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JOURNAL OF ECONOMIC ENTOMOLOGY

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Shade Tree Insects and Sprays, 1937

E. P. Felt and S. W. Bromley, *Bartlett Tree Research Laboratories, Stamford, Conn.*

Insects of Holly.—A serious infestation of the holly leaf miner, *Phytomyza ilicicola* Loew, was noted last spring on an estate in Greenwich, Conn. Leaves infested with the partly extruded puparia were collected and treated in the laboratory with a summer volck and nicotine combination. Volck was used at 2 per cent, nicotine sulfate at 1 to 800. The leaves were dipped, rather than sprayed, on May 14, but even under these conditions the kill was considered unsatisfactory. In all, 63 puparia were present in the 20 leaves so treated. On May 21, the first emergence of adult flies took place. A kill of 82.5 per cent was estimated to have resulted from the treatment.

Tests along a different avenue of attack were then conducted. It was found both with experiments under laboratory conditions and by tests in the open that arsenate of lead sprayed on the newly developing foliage at the time flies were abundant resulted in a rather quick killing. The effects of spraying were marked. The unsprayed foliage in the cage was practically destroyed by the numerous oviposition punctures, whereas on the sprayed leaves there was practically no damage. In this test conducted on May 25, 1937, arsenate of lead at the rate of 5 pounds to 100 gallons of water plus a suitable spreader and sticker (*S.S.S. Spreader*) at the rate of 1 pound to 100 gallons of water was used. A similar gratifying degree of protection was obtained by spraying infested holly trees in the open, the application being made at the time the flies were becoming abundant. These tests were prompted by the report that, in general estate spraying, it was noted that hollies sprayed with arsenate of lead were relatively free from this pest.

Insects of Dogwood.—Investigations on the dogwood club gall were continued this year. A number of midges were reared from several hundred galls collected the preceding season, and two species were obtained in some numbers, namely the strikingly-colored *Mycodiplosis alternata* Felt and a species of *Porricondyla*, 20 of the former and 26 of the latter. A few other species were reared. These latter were evidently inquilines or predators. The probabilities are, in the estimation of the senior author, that the *Mycodiplosis* is the producer of the gall, though the relative abundance of the *Porricondyla* raises a doubt as to its relation to this deformity, since a number of related species of *Porricondyla* have been reared from the galls of other insects under conditions which suggest they are inquiline in habit rather than gall producers. Additional data are being sought and some 2000 galls were collected this past fall in the hope that rearings next spring will establish beyond question the identity of the producer. This latter is of interest since the earlier work of Beutenmüller indicated that the gall producer was *Lasioptera clavula* Beutm. Observations in 1936 showed that the larvae deserted the galls late in September or early in October. Last year, 9 out of 14 galls were empty by October 7th. Collections this past fall indicated that by October 15th, 60 per cent of the galls were empty.

Experiments of the past season show that spraying dogwoods in shaded areas, just as the adults were issuing, with a molasses-nicotine combination similar to that used for the control of the boxwood leaf miner gave some control. However, control was not attained on dogwoods exposed to full sunlight. This was probably due to the rapid drying of the spray in the open areas. In these tests, molasses was used at the rate of 1 gallon to 10 gallons of water, nicotine sulfate at 1 to 800. Destroying the galls in the early fall before

mid-September should give a reasonably satisfactory control on isolated plantings.

INSECTS OF ELM.—A large number of smaller European elm bark beetles, *Scolytus multistriatus* Marsham were reared early this season, and about 60 each in a series of additions were caged on two small elms, one thoroughly sprayed with arsenate of lead plus a sticker and the other unsprayed. The sprayed tree was only lightly chewed by the beetles, while the unsprayed tree was eaten so badly that much of the bark was removed and a large portion of the top died from mechanical injury.

Similar results were obtained in a replication of the test, in which slightly over 100 beetles were used in each cage. Potted American elms one to two feet high were used. In the first test, the tree was thoroughly sprayed with arsenate of lead powder at the rate of 5 pounds to 100 gallons plus *S.S.S. Spreader* at ½ pound to 100 gallons and subsequently infested with the bark beetles after the spray had thoroughly dried. The application was made on June 19, 1937. The second tree was sprayed on July 8 with arsenate of lead powder at 5 pounds to 100 gallons plus *S.S.S. Spreader* at 2 pounds to 100 gallons. Using the spreader at this high rate apparently produced a greater runoff of the arsenate. There was some chewing of the bark although there still remained a sufficient amount of poison on the twigs to prevent serious injury. In the check which was unsprayed, the beetles chewed the bark so badly that the tree died down to the ground. The scars in the twig crotches were not nearly so numerous or so deep in the case of the sprayed trees as in the case of the unsprayed. At the end of the growing season, the scars on the sprayed trees were completely healed over and presumably there was relatively minor cambium injury in spite of the heavy beetle infestation.

In the field, one might expect a greater protection than with the superabundant infestation under cage conditions, although this would be offset to some extent by the washing off of the spray residue by rains.

These data indicate a marked degree of protection for poisoned elm twigs and justify the senior author's qualified recommendation of four years earlier, namely that when spraying valuable trees in areas where the Dutch elm disease occurs it is advisable to poison the twigs so far as possible.

A preliminary report was submitted last year on the balloon work planned to show wind drift tendencies from areas where the Dutch elm disease occurs. Since the presentation of this data there were received, as expected, some additional tags and it is interesting to note that the returns from the 1936 releases continued throughout the winter to the end of last April, tags being received every month from October through the winter, though the one received in February was actually found the very last of January.

This work was continued the past season, over 4900 balloons being released from North Stamford. The liberations were restricted largely to periods when the drift was northerly, mostly northeasterly, but occasionally southwesterly, because the experience of last year indicated that easterly and especially southeasterly drift resulted in many balloons being lost at sea. This year there were 238 returned tags, well toward 5 per cent, a larger number than was received from the 1936 liberations. More are to be expected in the next six months.

The drift this past season as the year before was, much of it, northeasterly. The more noteworthy returns were 10 from Rhode Island, 2 from lower Cape Cod, 1 from near Worcester and 1 from Stoneham near Boston, Mass., 1 each from Chester and Portsmouth in southern New Hampshire, and 1 from Popham Beach at the mouth of the Kennebec River in Maine; 2 from near Binghamton, N. Y. showed a marked northwesterly drift; 5 from the portion of New Jersey south of Perth Amboy to Asbury Park and 2 from the immediate vicinity of Philadelphia indicated a south or southwesterly drift. The marked northeasterly, northwesterly and southwesterly drifts were not duplicated in 1936. It is interesting in connection with the Dutch elm disease to note that balloons were returned this year from Branford and Old Lyme, Conn., two towns where Dutch elm diseased trees had been found in earlier years. These data give additional support to the opinion advanced earlier by the senior author to the effect that wind drift may be an important factor in

the dissemination of insects carrying the Dutch elm disease.

INSECTS OF FILBERT.—Strawberry rootworm beetles, *Paria canella* Fabr. were unusually abundant on the filbert plantings at the laboratory this past year, probably because the filberts were not sprayed with arsenate of lead during the season. Heretofore this insect has been controlled by such sprays, but marginal burning of the leaves had resulted in earlier years indicating that the filberts are susceptible to arsenical injury. This was established by the experiment of last year. Cryolite was used on a few of the shrubs in place of arsenate of lead and measurable though temporary control was obtained. The comparative lack of adherence of this material permitted considerable injury later in the season.

INSECTS OF BEECH.—An unusual occurrence was the great abundance of the oystershell scale, *Lepidosaphes ulmi* (L.), on the smaller branches of woodland beech at Great Barrington, Mass. The scale insects were so numerous as to kill a considerable proportion of the small twigs, especially on the lower branches of the trees. The infestation was easily recognized in midsummer by the distinctly brown appearance resulting from the terminal clusters of dead leaves.

INSECTS OF RHODODENDRON.—Grubs of the broad-necked root borer, *Prionus laticollis* (Drury), were found boring in flowering dogwood at Port Washington, Long Island. A tree with a trunk diameter of some four inches had been partly girdled five or six inches below the surface of the ground. Occasionally this species invades living rhododendron roots, especially those growing in woodlands.

Roundheaded apple tree borers, *Saperda candida* F., were reared in numbers from *Cotoneaster* stems in Darien, Conn. The borers were sufficiently abundant to cause considerable injury.

Mr. W. W. Ratcliff of Philadelphia, Pa. recently sent in specimens of rhododendron from an estate in that area. These specimens were found to be badly infested by the azalea bark scale, *Eriococcus azaleae* Comst. The foliage was rather thickly covered with sooty mold, and the bark of the stems rough and malformed. Mr. Ratcliff stated that 35 to 50 large plants were affected by this insect and that some were quite severely damaged. The infestation was confined apparently to one group of rhododendrons, while other plantings on the estate did not seem to be affected. Probably a thorough and forcible spraying with dormant oil just before the new growth starts in the spring would give control. On a small scale the infestation could probably be eradicated by scrubbing with a brush, employing the same method as that used for the control of the beech scale.

INSECTS OF VARIOUS DECIDUOUS TREES.—A comparative test of arsenate of lead, cryolite and derris-rosin residue emulsion was conducted on May 14, 1937, as part of a cooperative National Shade Tree Conference project initiated by Dr. C. C. Hamilton. A woodland border comprising deciduous trees up to 80 or 90 feet tall as a maximum—most of them considerably lower—lightly infested with the young caterpillars of the fall cankerworm, *Alsophila pometaria* (Harr.), and the pin oaks with young larvae of the leaf roller, *Argyrotoxa semipurpurana* Kf., was sprayed with power sprayers. The woodland border was marked off into sections. Five hundred gallons of derris powder said to contain 4 per cent rotenone and 15 to 16 per cent total ether extractives at the rate of 4 pounds to 100 gallons plus rosin residue emulsion at 2 quarts to 100 gallons were applied to the first section. The second section was sprayed with *Kryocide Cryolite* at 4 pounds to 100 gallons plus *S.S.S. Spreader* at 2 pounds to 100 gallons, 500 gallons being used in all. The remainder was sprayed with arsenate of lead at 5 pounds to 100 gallons plus ½ pound of *S.S.S. Spreader* to 100 gallons, 800 gallons of this being used to complete the application

The applications were made in the morning. The weather conditions were cloudy and calm. The temperature was 63 degrees F. during the application. In mid-afternoon a heavy shower of rain fell. Observations on control were made shortly after the spraying and again on May 18. General observations followed thoughout the season. The rain mentioned washed off the cryolite from the upper surfaces of the leaves quite generally and also the derris, but the arsenate of lead stuck for several months.

On the young cankerworms, a good initial kill was obtained with all three materials, the most lasting protection being

obtained with arsenate of lead. In the case of the pin oak leaf rollers, the derris, which appeared to be most effective as a contact spray, gave little control, as the larvae for the most part were protected by the roll of the leaf. The cryolite gave much better control, while arsenate of lead gave complete protection. No spray injury was noted in any of the trees sprayed. The list included white, black, red and scarlet oaks, pin oak, shagbark and pignut hickories, chestnut, willow, mountain ash, gray birch, white ash, red maple, sugar maple and American elm.—12-17-37.

Control of the European Pine Shoot Moth

R. B. FRIEND and G. H. PLUMB, *Connecticut Agricultural Experiment Station, New Haven*

During the seasons of 1936 and 1937 a series of experiments was carried out with the aim of increasing the efficiency of control, by the use of insecticides, of the European pine shoot moth, *Rhyacionia buoliana* (Schiff.). Friend and Hicock (1935) recommended a mixture of 3 pounds of lead arsenate and 1 quart of fish oil in 100 gallons of water to be applied twice: once, about June 22 and again 10 days later. This has given satisfactory protection against bud injury, but the authors have felt that the timing of the applications might be changed to advantage, and that the amount of spray material required for complete coverage is excessive.

The larva of the shoot moth bores into the bases of the new needles on the upper side immediately after hatching, in June and July. After living a few weeks in the needle base, it leaves its habitat and bores into a bud. In the plantation in which the experiments reported here were carried out, the first observed entrance of larvae into buds was July 24, 1936, and July 13, 1937. If the larvae are very abundant, most of the needles at the tip of the twig may be killed, which results in the death of this part of the tree. This type of injury is quite commonly found on the terminal growth of the main stem of young red pines when the infestation is heavy. The most common serious injury, however, is to the buds and shoots. For preventing either type of injury it is essential to secure a deposit of insecticide at the junctions of the needles and twigs on the new growth in order to kill the young larvae. This necessitates a heavy application of spray materials. A suitable spreader might permit a decrease in the amount of spray material necessary for good control, and it might also increase the length of time the insecticide adheres. The longer the insecticide adheres, the better the results. The pines are growing during the period when the larvae are hatching; therefore, the proper timing of the spray application is important.

MATERIALS USED.—Due to the amount of work involved in checking the results of the experiments, the authors have limited the insecticides to lead arsenate, derris and cubé. Derris and cubé are similar in their insectidal constituents and physical properties, (Clark 1929), and when the insecticidal constituents occur in nearly equal amounts, the two materials appear to have approximate toxicities (Huckett & Hervey 1935). They may be considered as the same insecticide in the work reported here. The lead arsenate was the standard acid form. The ground derris root used in 1936 had a rotenone content of 4 per cent and total either extractives of 14 per cent, and the ground cubé root used in 1937 had the same analysis.

Derris has been shown to possess the qualities of a stomach poison, a contact insecticide, and a repellent, (Barrett 1937; Fleming & Baker 1936; Tischler 1935; Turner 1932), depending to a certain extent on the insect against which it was used. Lepidopterous larvae react to it, in varying degree, from highly susceptible to highly resistant; moreover, there are variations in susceptibility among different individuals and among larval stages within a species (Huckett 1936; Klinger 1936). Powdered derris or cubé root used as a dust or a suspension in water has been found very toxic to certain of these insects; and rotenone, the principal toxic constituent, has been shown

to be 30 times more toxic than lead arsenate to some species (Campbell 1932; Hansberry & Richardson 1936).

Igepon T, SS_3, waterproof glue, powdered skim milk and menhaden fish oil were used as spreaders and stickers. *Igepon T* is an alkyl sulfonate, and SS_3 is sodium oleyl sulfate with a little sodium lauryl sulfate plus a synthetic resinous sticker. The nature of these two materials has been discussed by Roark (1937). The *Igepon* was furnished mixed with the lead arsenate by the manufacturer. If mixed with distilled water at the concentrations used, the *Igepon* 10 per cent solution, without lead arsenate, would have a surface tension against air at 27 degrees C. of 37.2 dynes per cm.; *Igepon*, 5 per cent, of 39.5 dynes; and SS_3 45.5 dynes.

Goodhue & Fleming (1936) published the results of tests for adhesiveness of of some of the above materials when used with derris. The mixtures were sprayed on glass plates, dried, and subjected to falling water equivalent to 2.5 inches of rainfall. Under these conditions, using 2 per cent derris and 1 per cent sticker, the investigators found that the total loss of derris was 56 per cent in the case of raw menhaden oil, 62.5 per cent in the case of skim milk powder, and 88 per cent where no adhesive was used. In tests on bean foliage, using 1 per cent derris and 0.5 per cent sticker, these authors found the relative amounts removed were 74.5 per cent from string bean leaves and 50 per cent from lima bean leaves when raw menhaden oil was used as a sticker as compared to 92 per cent and 92.5 per cent, respectively, when no adhesive was used. Goodhue & Fleming (1936) recommended the use of rosin residue as an adhesive on the basis of their trials. This material was not used in the field experiments reported here. It is very doubtful if the loss of insecticide due to rainfall is as great on red pines as on glass plates in the laboratory. In the experiments carried out in 1937, fish oil (menhaden) was used as an adhesive with lead arsenate and powdered skim milk with cubé.

All experiments were carried out in the red pine plantation of Dr. Carl Burdick in Wilton, Conn. The trees were of the same age, planted 6 feet apart, from 6 to 11 feet in height, and well infested. Inasmuch as the spraying machine could not be driven between the trees, a Latin square arrangement of plots was not possible. A double nozzle was used in spraying, and the pressure at the pump was kept at about 300 pounds. An interval of two or three rows was left between plots in order to eliminate any error due to drifting spray. The check trees were located a suitable distance from the ends of the sprayed plots.

The infestation at the time of spraying in 1936 was heavier on the west side of the plantation than on the east side. This made it necessary to use a separate group of unsprayed trees on each side for estimating the normal infestation in that year. The plots were confined to the south end of the plantation. In 1937 the plots were confined to the north end of the west side. The infestation was fairly uniform. In any given part of this plantation the extent of infestation on individual trees varied rather widely.

In determining the extent of infestation per tree the number of injured tips was the criterion used. When the larva attacks a bud, a flow of pitch ensues, and this pitch hardens into a conspicuous mass which remains on the tip throughout the fall and winter. The presence of such a pitch mass indicates larval injury but not necessarily a living larva. There is a normal mortality of larvae in the fall, sometimes as much as 50 per cent before the beginning of severely cold winter weather. Inasmuch as the object of controlling the insect is to prevent bud injury, the number of injured tips per tree should indicate the efficiency of the spraying operation.

EXPERIMENTS IN 1936.—The spray materials applied, amounts used, trees sprayed and results attained are given in table 1. The plots were sprayed as follows: (1) June 10; (2) June 22; (3) June 10 and June 22; (4) July 7.

Only the significant data are included in the table. No insecticide was effective when applied June 10 only; hence results attained by this application are omitted. Where no applications were satisfactory, only the best results are given. In estimating the number of injured tips per tree, five trees were examined in each plot. The number of injured tips per tree varied on the unsprayed trees (check trees) rather widely, as the probable errors of the means indicate. The results are significant in several respects. The addition of *Igepon* to lead arsenate did not result in

an appreciable degree of control, the greatest reduction in injured tips being 23 per cent for the application of July 7 with the lead arsenate containing 5 per cent *Igepon*. Lead arsenate and SS_3 applied July 7 gave a 63 per cent reduction in injured tips, but the other applications of this material were less efficient. Lead arsenate and waterproof glue applied June 10 and June 22 (two applications) resulted in a 72 per cent reduction in injured tips, sprayed July 7, with a 61 per cent reduction in injured tips per tree, is significantly lower than the plot sprayed with the same material June 22 (80 per cent) and the plot sprayed with derris combined with powdered skim milk July 7 (75 per cent). Of the single sprays of derris, that applied June 22 appears most efficient. Powdered skim milk gave slightly better results than SS_3 as a spreader and adhesive.

Table 1.—1936 Spraying Experiments.*

Insecticide	Date Applied	No. of Trees Sprayed	Infested Tips per Tree	Infested Tips per Tree on Checks	Per Cent Reduction
Lead Arsenate 3 lbs., Fish Oil 1 pint	(6-10-36 / 6-22-36)	17	21.2±4.25	46.6± 7.92	+55
	7- 7-36	18	21.6±2.19	81.8±11.80	+74
Lead Arsenate 3 lbs., Waterproof Glue 1 lb.	(6-10-36 / 6-22-36)	16	23.0±2.02	81.8±11.80	+72
	7- 7-36	18	32.4±2.91	81.8±11.80	+60
Lead Arsenate 3 lbs., SS_3 3 oz.	7- 7-36	18	30.6±1.97	81.8±11.80	+63
Lead Arsenate Containing 5 per cent *Igepon* 3 lbs. 5 oz.	7- 7-36	18	35.8±3.37	46.6± 7.92	+23
Lead Arsenate Containing 10 per cent *Igepon* 3 lbs. 5 oz.	7- 7-36	18	37.8±3.31	46.6± 7.92	+19
Derris 4 lbs., SS_3 3 oz.	6-22-36	78	16.2±1.25	81.8±11.80	+80
	(6-10-36 / 6-22-36)	12	22.8±2.23	81.8±11.80	+72
	7- 7-36	16	18.4±1.10	46.6± 7.92	+61
Derris 4 lbs., Powdered Skim Milk 1 lb.	6-10-36	58	30.0±5.56	81.8±11.80	+63
	6-22-36	72	16.6±0.69	81.8±11.80	+80
	(6-10-36 / 6-22-36)	16	15.0±0.77	81.8±11.80	+82
	7- 7-36	16	11.8±1.47	46.6± 7.92	+75

* The amounts of insecticides given were mixed with 100 gallons of water.

and the application of July 7 resulted in a 60 per cent reduction. Lead arsenate and fish oil applied July 7 gave a reduction of 74 per cent in injured tips, and the plot sprayed June 10 and 22 showed a reduction of 55 per cent.

The derris plots were fully as good as, if not better than, the lead arsenate plots. The best derris plot, derris with powdered skim milk applied June 10 and 22, gave a reduction of 82 per cent in injured tips per tree, whereas the best lead arsenate plot, lead arsenate with fish oil applied July 7, gave a reduction of 74 per cent. The wide variation between trees makes this difference of 8 per cent questionably significant. The derris with SS_3 plot

In comparing the relative efficiency of lead arsenate and derris as regards applications on different dates, the two insecticides show slightly different tendencies. All the lead arsenate mixtures gave best results with a single application July 7, except when used with glue. The lead arsenate with glue plots gave slightly better results with two applications (June 10 and 22) than with a single application July 7. The derris plots gave best results with a single application June 22 when SS_3 was used, and the same results with one application June 22 as with two applications (June 10 and 22) when powdered skim milk was used. The results from a single application (June 10) were poor.

The efficiency of a spreader in reducing the amount of spray material necessary per tree is questionable. The trees were sprayed until the insecticide accumulated at the junctions of the needle bases with the twigs. The results with lead arsenate applied June 22 show waterproof glue to be far superior to the other materials, but the results attained by spraying July 7, when an attempt was made to get the same amount on each tree, show little difference among fish oil, glue and SS_3, although fish oil was a little superior. SS_3 gave decidedly better results than *Igepon*, but *Igepon* was inferior to fish oil. If any other material used were to be substituted for fish oil on the basis of this work, it would have to be waterproof glue, but the difference between the two is not great. The results with derris indicate that powdered skim milk is slightly superior to SS_3. In any case it appears that 1.5 to 2 gallons per tree is necessary on trees of this size. These results are obviously none too conclusive. No experiments were carried out in which different amounts of the spreaders were used, and such tests, to be of practical value, would have to simulate field conditions where a deposit of insecticide is necessary on a very localized part of the tree.

The results attained in 1936 indicate that spraying early in June is not efficient and that a mixture of 4 pounds of derris and 1 pound of powdered skim milk is superior to a mixture of 3 pounds of lead arsenate and 1 pint of fish oil, when each mixture is added to 100 gallons of water. It was decided to continue the experiments in 1937 with these two insecticides and attempt to determine their relative merits as well as the best time to apply them.

EXPERIMENTS IN 1937.—The only two insecticidal mixtures used in 1937 were those two mentioned in the paragraph above. Four dates of application were selected on the basis of the time of oviposition, the incubation period of the eggs and the duration of effectiveness of the insecticide on the trees, that is, June 14, June 22, July 2 and July 12. All combinations of one, two, three and four applications were made. The plots consisted of 5 trees each, and 10 unsprayed trees were used to check the results.

The plots were arranged so that they could be sprayed by use of a long hose, the machine being kept in the road. It was possible, with the equipment available, to spray at most three plots, totaling 15 trees, in each row. Two rows of unsprayed trees were left between consecutive rows of sprayed trees, and in no case was one row used for more than one insecticide. In any one row there were thus one, two or three plots,all receiving applications of one material but no two plots being sprayed on the same combination of dates. Blocks of lead arsenate plots alternated with blocks of cubé plots. The check trees were in a row opposite the ends of the sprayed plots.

The number of injured tips per tree was determined on all trees, 160 in number, during the fall of 1937. Only the best single, double and triple applications and the plot sprayed four times are included in the data given for lead arsenate in table 2. All data for cubé are included.

The best single lead arsenate application, July 2, gave 41 per cent reduction in injured tips, and the best double application, July 2 and 12, gave 87 per cent reduction in injured tips. The best triple application, June 22, July 2, July 12, gave 91 per cent reduction in injured tips. The trees sprayed four times were no better than those sprayed three times. The difference between the best single application and the best double is significant. but the difference between the best double and the best triple is not significant. The odds against so great a difference being due to chance alone are only 4:1. The difference between the poorest triple application, 80 per cent reduction, and the best triple, 91 per cent reduction, is significant, the odds being 45:1. The single applications of lead arsenate were in no case very significant, as a comparison of the best single with the unsprayed check trees showed odds of only 18.8:1. The variation in results between trees sprayed on any one date with lead arsenate was great, and the data indicate clearly that a single application of this material is of little use. It also appears clear that two applications one July 2 and one July 12, gave as good results as any other two or three applications, and four applications gave no better results than three.

The best single application of cubé, 89 per cent reduction in injured tips, was made July 2, and the best double application, 99 per cent reduction, July 2 and

July 12. The difference between these two plots is significant, the odds being very high. The best double application is also superior to any other double application, the lowest odds being 78.5:1. Under field conditions any degree of control exceeding 90 per cent reduction in injured tips ought to be satisfactory, and the relative merits of applications giving such results might be open to question. Every plot sprayed with cubé gave results significantly better than the unsprayed check trees, the odds in the poorest plot, a single spray applied

a. Powdered skim milk, .57 grams
b. Rosin residue emulsion. 1.8 c.c.
c. *Ultrawet*, .3 grams

2. Lead arsenate, 1.7 grams+water 473 c.c.
   a. Menhaden fish oil, .6 c.c.

These amounts give the proportions per 100 gallons as follows: lead arsenate, 3 pounds, plus fish oil, 1 pint; cubé, 4 pounds, plus powdered skim milk, 1 pound; cubé, 4 pounds, plus rosin residue emulsion, 3 pints; cubé 4 pounds, plus *Ultrawet*, 0.5 pounds. The rosin residue

Table 2.—1937 Spraying Experiments.

Insecticide	Date Applied 6-14-37	6-22-37	7-2-37	7-12-37	Infested Tips per Tree	Per Cent Reduction
Lead Arsenate 3 lbs., Fish Oil 1 pint			×		40.2±7.55	+41
			×	×	8.8±1.35	+87
		×	×	×	5.8±0.81	+91
	×	×	×	×	6.0±1.69	+91
Cubé 4 lbs., Powdered Skim Milk 1 lb.*	×				38.2±6.94	+44
		×			12.6±1.82	+81
			×		7.8±0.94	+89
				×	27.6±2.23	+59
	×		×		6.6±1.62	+90
	×			×	5.6±0.55	+92
		×	×		4.2±1.15	+94
		×		×	4.0±0.88	+94
			×	×	0.6±0.27	+99
	×	×	×		1.8±0.34	+97
	×		×	×	0.4±0.27	+99
	×	×		×	1.6±0.47	+98
		×	×	×	0.8±0.13	+99
	×	×	×	×	0.4±0.16	+99
None—check trees					68.1±6.11	—

* Due to an unfortunate mistake in spraying, no trees were given the double application June 14 and 22. This is not of serious consequence, as the June 14 single application gave the poorest results.

June 14, being 31.4:1. The uniformly good results attained with this material are striking.

In order to obtain some indication of the durability of ground cubé root and lead arsenate on pine twigs, a series of twigs was sprayed in the field and sample lots brought to the laboratory after various intervals of time. A number of newly hatched larvae which had not fed were placed on each tip. After an interval of 5 to 7 days the number of bored needle clusters on each twig was determined. Although a small number of larvae was used in each test, the results were significant in some respects.

The following materials were employed:

1. Ground cubé root, 2.27 grams+water 473 c.c.

emulsion was the product of the Hercules Powder Co. The constituents and characteristics are given by Goodhue & Fleming (1936). The *Ultrawet* is a sodium sulfonate of crude petroleum prepared by the Atlantic Refining Co. Its use as a spreader is discussed by Walker (1937). At a temperature of 27 degrees C. the surface tension against air of the concentration employed, in distilled water, is 40 dynes per centimeter.

The data are given in table 3. Up to six days' exposure the results for all materials were similar, in that no more than one or two needle clusters were bored. The significant data are for exposures of six days and over, and only these are included in the table.

After being exposed to the weather for

periods up to nine days the materials were about equally effective. After an exposure of 11 days the cubé-rosin residue was not so effective as the other mixtures. This 11-day period represents one test only and does not give a very satisfactory basis for comparison, but it indicates that rosin residue emulsion as a spreader and sticker for cubé on pine tips was no more efficient than the other materials used. The results attained in all tests up to and including the 11-day period support this conclusion. One or two tests at 12- to 14-day periods with all mixtures show a rapid decline in effectiveness except with lead arsenate combined with fish oil. Only 5 or 10 larvae were used per test at these longer periods, and the figures are not given in the table. The twigs were all thoroughly sprayed until the insecticide ran off freely. The rainfall and total hours of sunshine as recorded by standard U. S. Weather Bureau equipment are given in the table.

Table 3.—Duration of effectiveness of cubé and lead arsenate, Hamden, Conn., June, 1937, insecticide tests*

Insecticide	Days Since Sprayed	No. of Twigs	No. of Larvae	Bored Needle Clusters per 20 Larvae	No. Larvae Surviving (per 20 Larvae)	No. Dead Larvae Found (per 20 Larvae)	Total Rainfall	Total Sunshine in Hours
Cubé and milk	11	3	20	3	2	10	1.06 in.	116
Cubé and milk	8	4	40	4	2.5	3	.84 in.	71
Cubé and milk	6	2	20	0	0	0	.37 in.	59
Cubé and Rosin Residue	11	3	20	11	8	5	1.06 in.	116
Cubé and Rosin Residue	9	4	40	6	4	8.5	1.04 in.	77
Cubé and Rosin Residue	7	1	10	4	4	8	.37 in.	64
Cubé and Rosin Residue	6	1	10	2	2	12	.84 in.	59
Cubé and *Ultrawet*	11	3	20	4	3	6	1.06 in.	116
Cubé and *Ultrawet*	9	4	40	5	3	4	1.04 in.	77
Cubé and *Ultrawet*	7	1	10	2	2	2	.37 in.	64
Cubé and *Ultrawet*	6	1	10	2	0	12	.37 in.	59
Lead Arsenate and Fish Oil	11	3	20	4	2	6	1.06 in.	116
Lead Arsenate and Fish Oil	8	4	40	1	1	5.8	.84 in.	71
Lead Arsenate and Fish Oil	6	2	20	3	1	5	.37 in.	59
Check, No Treatment		4	50	14	9	.4		

* Inclusive spraying dates—June 23–29, 1937.

DISCUSSION OF RESULTS.—A comparison of the results attained by spraying with lead arsenate and with cubé show that cubé was not only more efficient in reducing the infestation, but that it produced more uniform results. This may be due in part to the superiority of powdered skim milk over fish oil as a spreader. If this were true, then the differences between the two insecticides would tend to decrease as the number of applications increased, other things being equal. This is what actually occurred. It is also true that, if one material were a more powerful insecticide than the other, the same phenomenon would be observed. The data do not permit a comparison between the absolute insecticidal properties of the two materials, since comparable dilutions were not employed. All we can say is that, at the dilutions used and with the spreaders and adhesives used, cubé was much superior to lead arsenate. One application of cubé was as efficient as three or four applications of lead arsenate. The difference between 5.8 ± 0.81 injured tips per tree and 7.8 ± 0.94 infested tips per tree is not significant.

The best time to spray is about July 2 for a single application and about July 2 and July 12 for a double application. This is shown by the results attained with both lead arsenate and cubé. In previous years earlier spraying dates with stomach poisons have been advocated (Friend & West 1934; Friend & Hicock 1935), but the results attained in 1937 show that earlier applications are not so efficient. Hamilton

(1931) sprayed pines about the middle of June in New Jersey and attained good results, but he used a contact insecticide. There may be an earlier emergence of moths in New Jersey than in Connecticut. Glasgow and Van Buren (ca. 1932) obtained their best results in controlling this insect with a spray containing "cubé or derris extract in a miscible ('soluble') pine oil solvent or carrier, containing 5 per cent rotenone,—1½ pints; miscible ('soluble') pine oil—2 gals."; in 100 gallons of water. The rotenone content of the mixture approximates very closely that of 4 pounds of derris or cubé containing 4 per cent rotenone in 100 gallons.

Rainfall* may have affected the efficiency of some of the applications, particularly if we assume that heavy rains wash off more insecticide than intermittent light showers which total the same amount. In both 1936 and 1937, the early June spray was exposed to heavier rainfall than any other application. On June 13, 1936, three days after spraying, 4.02 inches of rain were recorded in 24 hours. On June 22, 1937, eight days after spraying, 2.05 inches were recorded, and on June 18, four days after spraying, 0.67 inch was recorded. Between the application of the spray of June 22, 1936, and that of July 7, 1936, only 0.47 inch of rain fell, the greatest amount in 24 hours being 0.18 inch. Between the application of June 22, 1937, and that of July 2, 1937, 1.16 inches fell, of which 0.45 inch was recorded on June 29 and 0.54 inch on June 30, totalling 0.99 inch for one storm. The results of the applications of early June were poorer both years than those of June 22. In 1936, 0.85 inch of rain was recorded July 14 and 0.84 inch July 18. In 1937 between the applications of July 2 and July 12, 0.83 inch of rain fell, 0.69 inch on July 12. The early July applications were relatively more efficient in 1937 than in 1936. During the 10 days following the application of July 12, 1937, 1.00 inch of rain fell, 0.77 inch on July 16. The application of July 12 was of the same efficiency as that of July 2. The effect of rainfall alone on the efficiency of the different applications is difficult to determine, but it appears that the early June application of each year may have suffered. However, the general trend of the effect of different spraying dates was so pronounced both years that it does not appear to have been affected by rainfall alone. This is particularly striking if the last two applications of 1936 are compared with the last three of 1937.

Although exposure to sunlight may have a deteriorating effect on the toxicity of derris and cubé, these insecticides remained effective for a sufficient length of time under the conditions. During the 15 days following the application of June 22, 1936, 166 hours of sunshine were recorded, and during the 10 days following the June 22, 1937, and July 2, 1937, applications, the total recorded sunshine was 83 hours and 125 hours respectively. During 9 days after the July 12, 1937, application, 89 hours were recorded. The effectiveness of the insecticide depends so much on the habits of the insect that these may offset the durability of the insecticides. The relative effectiveness of the applications of July 2, 1937, and July 12, 1937, indicate that the cubé remained toxic a long time.

The laboratory experiments with newly hatched larvae on sprayed twigs show that, after an exposure of 11 days in the field, ground cubé root used with powdered skim milk or *Ultrawet* was as effective in preventing boring as was the lead arsenate and fish oil combination.

The 1937 results supported those attained in 1936 as respects both the relative effectiveness of dubé or derris with powdered skim milk, when compared to a lead arsenate and fish oil mixture, and the greater efficiency each year of spraying early in July rather than early in June.

SUMMARY.—Field experiments on the control of the European pine shoot moth on red pine in Connecticut have shown that spraying with a mixture of 4 pounds of ground derris root or ground cubé root and 1 pound of powdered skim milk in 100 gallons of water is superior to spraying with a mixture of 3 pounds of lead arsenate and 1 pint of fish oil in 100 gallons of water. One application of cubé about July 2 is as effective as three or four applications of lead arsenate at 10-day intervals in June and July. Two applications of cubé, one July 2 and one July 12, are significantly more efficient in reducing tip injury than one application July 2. As a spreader and sticker, powdered skim

* All precipitation records are for Norwalk, Conn., about eight miles from Wilton.

milk is as efficient as any other materials tried at the concentrations used. It was found that spraying during the first half of June did not give good results in controlling the insect in 1936 and 1937.—12-30-37.

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Experiments for Control of the Pine Needle Scale, *Chionaspis pinifoliae* (Fitch)*

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The pine needle scale, *Chionaspis pinifoliae* (Fitch), is widely distributed in the United States and has been recognized as a pest of pine, spruce and certain other evergreens for many years. This insect is usually more common and destructive on older trees in home, ornamental and reforestation plantings, though it may also prove to be a pest of older trees in commercial nurseries. The infestations which have come to our attention were most serious and injurious on Scotch pine, *Pinus sylvestris* L.; red pine *P. resinosa* Ait.; Austrian pine, *P. nigra* Arn.; Mugho pine, *P. Mugo* Turra; and Swiss stone pine *P. cembra* L.

The feeding of these insects on the cell sap causes definitely lighter colored areas on the needles, due to the depletion of chlorophyll, and in cases of heavy infestations the trees become weakened, growth of the affected branches may be retarded and premature defoliation may occur. In addition, infested trees in ornamental plantings become unattractive, owing to the whitish appearance of the tree and needles caused by the presence of innumerable scales and also to the lack of vigor of the tree, which results from the feeding of the insects.

SEASONAL HISTORY.—The time of ap-

* Approved November 16, 1937, by the Director of the New York Agricultural Experiment Station for publication as Journal Paper 232.

Table 1.—Dormant treatments for control of pine needle scale, 1936.

Treatment	Number Old Scale	Number New Scale	Ratio Young to Old	Percentage Decrease of Infestation	Percentage Efficiency*
Coal-Tar Oil, 2 per cent	1064	315	.296	70.4	93.1
Coal-Tar Oil, 4 per cent	1157	200	.172	82.7	96.0
Water-Gas Tar Oil, 2 per cent	1056	2809	2.660	−166.0†	38.3
Water-Gas Tar Oil, 4 per cent	1045	1992	1.906	− 90.6	55.8
Sunoco, 2 per cent	938	2375	2.531	−153.2	41.3
Sunoco, 4 per cent	810	677	.835	16.4	80.6
Scalecide, 2 per cent	852	4561	5.353	−435.3	0.0
Scalecide, 4 per cent	775	2928	3.778	−277.8	10.9
Lubricating Oil, 2 per cent	922	852	.924	7.6	78.6
Lubricating Oil, 4 per cent	772	532	.689	31.1	84.0
DN-Oil, 2 per cent	743	271	.364	63.5	91.5
DN-Oil, 4 per cent	1069	203	.189	81.0	95.6
Check	1100	4742	4.310		

* A ratio of 1 signifies 76.8 per cent efficiency.
† Figures preceded by minus sign represent an increase in infestation.

Table 2.—Dormant treatments for control of pine needle scale, 1937.

Treatment	Number Old Scale	Number New Scale	Ratio Young to Old	Percentage Decrease of Infestation	Percentage Efficiency*
DN-Oil, 1 per cent	592	0	0.0	100.0	100.0
Scalecide, 4 per cent	171	75	.438	56.1	96.8
Sunoco, 4 per cent	147	338	2.299	−129.9†	83.4
Coal-Tar Oil, 2 per cent	324	176	.543	45.7	96.1
Coal-Tar Oil 4 per cent	534	129	.241	75.8	98.3
Check	40	554	13.850		

* A ratio of 1 signifies 92.8 per cent efficiency.
† Figures preceded by minus sign represent an increase in infestation.

Table 3.—Summer treatments for control of pine needle scale, 1936.

Treatment		Number Scale Alive	Number Scale Dead	Percentage Alive	Percentage Efficiency
		First Brood			
Nicotine Sulfate Soap (Solids)	1–800 4 lbs.–100	53	1233	.41	99.54
Nicotine Sulfate Orthol-K Oil	1–800 1–100	28	730	.36	99.60
Orthol-K Oil	1–100	10	867	.11	99.87
Orthol-K Oil	1– 50	9	1470	.06	99.93
Check		2006	217	90.23	
		Second Brood			
Nicotine Sulfate Sodium Lauryl Sulfate	1–400 4 oz.–100	125	2165	.54	99.33
Nicotine Sulfate Orthol-K Oil	1–400 1–100	144	2870	.47	99.41
Orthol-K Oil	1–100	443	1259	2.60	96.78
Orthol-K Oil	1– 50	0	3828	0	100.00
Check		1396	332	80.78	

pearance and length of developmental periods in the life history of the insect appear to vary noticeably in different areas and are presumably affected by elevation, temperature and other factors. For example, Herrick (1931) working with this insect at Ithaca, New York, found that only one generation occurs in that immediate area, whereas the writer during 1936 and 1937 observed two generations each year at Geneva and Rochester. The approximate elevation at these points are 800, 600 and 500 feet, respectively. It is quite conceivable that such differences in elevation and possibly accumulated temperature would account for such variation in seasonal history from closely related areas. Such wide differences in the life cycle of the insect definitely show the importance of adequate information on life history in the formulation of control measures, particularly if recommendations relate to control of the young crawlers during the summer.

The information given here on seasonal history is based on observations where two annual generations occur. The insect overwinters primarily in the egg stage, although, it is not uncommon to find some female scales that pass the winter and then lay eggs the following spring. The eggs begin to hatch during late May, and hatching is usually complete by the first week in June. *Spiræa Vanhouttei* is in full bloom at this time.

The rapidity of hatching and development are affected to a large extent by seasonal conditions. During wet, cool periods the young nymphs, which at first are red in color, may remain beneath the old female scale for several days, but if the weather is warm the young nymphs move about freely and settle down on other portions of the needles shortly after hatching. If the infestation is heavy, some of the young remain permanently under the old female scale and continue their development without migrating to other portions of the needle.

During 1936 and 1937, hatching of the first generation was complete by the first week in June. The females of the first generation reach maturity by early July and commence oviposition about the middle of July. Nymphs of the second generation begin to appear about the third or fourth week in July, and hatching is usually complete by the early part of August. Egg-laying by second generation females begins about the middle of September but, as pointed out previously, some females do not oviposit until the following spring. In 1936 more than 80 per cent of the females had deposited at least some eggs by October 22, although some gravid females were found beneath the scales in the spring of 1937. Where two generations of the insects occur, the nymphs of the first generation settle for the most part on needles which have developed the previous year, while those of the second generation migrate in large numbers to the new needles, where they complete development and later deposit eggs.

CONTROL.—The satisfactory control of spruce gall aphid obtained through the use of creosote-tar oils by Gambrell (1934), of oystershell scale on apples by Hartzell & Moore (1937) as well as workers in other states and the lack of control of the form of oystershell scale on lilac by the author led to further tests to determine the effects of creosote-tar oils and other materials on the control of the pine needle scale.

The results reported in tables 1, 2 and 3 were obtained on Scotch and red pines at the Oak Hill Country Club, Rochester, N. Y., and on Swiss stone pine located on the Experiment Station grounds at Geneva, N. Y. Dormant treatments used in both 1936 and 1937 were diluted on the basis of actual oil content as indicated in tables 1 and 2 and were applied on April 20 and April 30 of 1936 and 1937, respectively. Summer treatments were applied on June 2 and August 14, 1936, for control of the crawlers of the first and second generations, respectively. Standard power spraying equipment was used in applying all of the mixtures.

In securing data on control, the following methods were employed: (1) for dormant treatments, the number of old and new scales were recorded to determine the influence of these materials on the eggs and overwintering females; (2) for summer treatments, counts of living and dead scales were taken since, in this case, only the young crawlers or those subsequently reaching maturity were involved. The method followed in calculating data was that used by Hartzell & Moore (1937).

It will not be necessary to discuss in detail the relative merits and control

efficiencies of the various materials tested as this information is given in tables 1, 2 and 3. It should be pointed out, however, that creosote-tar oil and DN-oil were apparently somewhat superior to the other materials used as dormant treatments at the dilutions employed. DN-oil, however, at both 2 and 4 per cent dilutions caused definite foliage injury and needle casting in 1936 but a 1 per cent dilution applied during 1937 was attended by only slight foliage injury on red pine and little or none on Scotch pine. With summer oil emulsions, no ill effects were observed either from dilutions of 1–100 or 1–50 during the past two seasons.

SUMMARY.—In summarizing it may be said that, while these experiments have not been conducted over a sufficient period to make definite recommendations, (1) coal-tar oil and DN-oil appear to be the best possibilities for use in dormant treatments, under the conditions of these tests, if diluted properly and (2) the use of nicotine sulfate with soap, nicotine sulfate with oil and oil sprays alone are effective in controlling the young crawlers. The oil and nicotine sulfate mixture possesses an added advantage of extending somewhat the normal effective spraying period of such a mixture as compared with nicotine sulfate and soap, since it is possible to obtain satisfactory control with the former mixture even after the nymphs have settled down and begun to secrete the scale. This fact was demonstrated during 1937 when an application of 2 gallons of summer oil emulsion and 2 quarts of nicotine sulfate to 100 gallons of water, applied July 10 for control of the first brood, gave an excellent kill.—12-17-37.

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Notes on the Locust Leaf Miner, *Chalepus dorsalis* Thunb.

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Black locust trees (*Robinia pseudoacacia* L.) in many parts of Virginia have been severely injured by the locust leaf miner, *Chalepus dorsalis* Thunb. This injury occurs year after year and in certain sections the foliage generally turns brown by midsummer. The burned appearance of the locust trees has been responsible for many inquiries. In Virginia the heaviest infestation of the locust leaf miner occurs in the western or mountainous section of the state. This insect has been found by Chittenden (1904) in the District of Columbia, Maryland and Virginia. Houser (1908, 1918) reported serious injury to foliage of the locust in Ohio on two different occasions. Felt (1912) reported the insect in New York; Symons & Cory (1913), in Maryland; Garman (1916), in Kentucky; and Britton & Zappe (1927), in Connecticut. The writer observed considerable injury caused by this insect in the Great Smoky National Park in eastern Tennessee during the summer of 1935.

In addition to this insect, there are several other leaf miners which are occasionally found in locust leaves. One of these, a lepidopterous insect, *Parectopa robiniella*, Clem., occurs on locust from early summer to late fall. It has been noted in several sections of Virginia and sometimes is abundant.

CHARACTER OF INJURY.—The injury to the foliage is caused by the feeding of the adult and the larva of the locust leaf miner. The injury caused by the adult is slight when compared with that by the larva. While the leaves are yet young, the feeding of the overwintered adult is characterized by small holes eaten entirely through the leaf, usually near the

tip. Later, when the leaves become tough, the beetles feed only on the upper surface, giving the leaf a netted appearance, which later causes it to curl and turn brown. This type of feeding is also characteristic of the adults of the new generation.

The larva forms mines by feeding upon the tissue between the upper and the lower epidermis. Except for entrance and exit punctures, the upper and lower surfaces are intact. Since the larva feeds on the parenchyma cells, the mine can be seen from either side of the leaf. This causes the leaf to assume a dead, parched appearance, which generally becomes conspicuous about the time the larva is ready to pupate. When infestations are heavy, the foliage turns brown as if scorched by fire. Though the injury has been severe for several years, no dead trees resulting from it have been observed.

EMERGENCE.—In the spring of 1937, the beetles appeared first on small trees, which seemed to be preferred. In this case, the trees were near favorable hibernation quarters consisting of leaves, grass and thick undergrowth. The infestation was generally spotted in any area. In certain sections, considerable injury was noted on some trees, while other trees, only a few hundred yards away, showed little injury. In the vicinity of Blackburg, Va., the first beetle was observed in 1937 on May 5. Each day thereafter several specimens were taken, and by May 15 they were present in large numbers. Little feeding was evident, however, by this time. By May 20 the beetles were feeding extensively in this locality. At this time the injured foliage on the young trees had begun to turn brown.

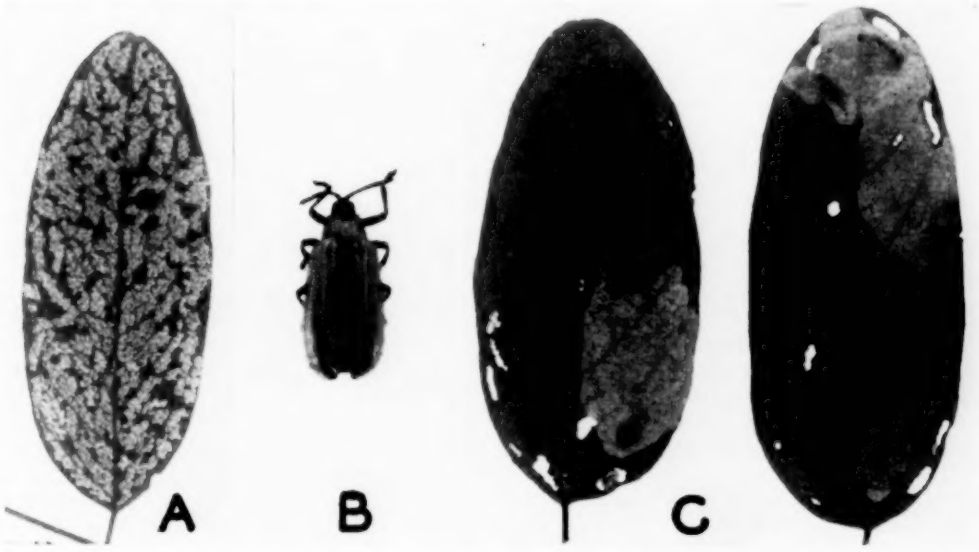

FIG. 1.—Injury to foliage by the locust leaf miner. A. Injury by adult in midsummer. B. Adult, about $2\frac{1}{2}$ times natural size. C. Leaves with mines made by larvae.

EGGS.—On May 24, 1937, the first eggs were deposited on the leaves of caged locust plants in the insectary, and the eggs were first observed in the field on the same date. A feeding period of 19 days occurred between the time the first adult was observed in the field and the date of the first oviposition. Eggs were very numerous in the field by the fifth of June.

The egg, when first deposited, is a reddish cream; but, after a short time, it turns to a dull, blackish color. The eggs are laid on the under side of the leaves and are glued together in small masses of three to five and covered with excrement. The first egg is deposited flat on the surface of the leaf and the remaining eggs so placed that they somewhat overlap the first. Owing to the excrement and the manner of deposition, the number of eggs cannot easily be determined. When the

egg mass is removed from the leaf, however, each egg is clearly visible from the under side. In this study, the number of eggs deposited varied greatly. When the beetles were under caged conditions, the largest number of eggs deposited by a single female was 116, the smallest number, 53, and the average for 10 individuals, 74.1 eggs.

LARVAE.—The length of the incubation period during 1937 varied from 9 to 11 days, depending on the temperature. The average for the eggs of 110 egg masses was 10 days. Upon hatching, each larva gnawed its way through the under side of the egg and entered the leaf through the epidermis. The young larvae which hatched from the same egg mass all occupied the same mine for three or four days, the number of days depending upon the number of larvae in the mine and the size of the leaf. They then ate through the epidermis, left the old mine and each re-entered another leaf. Two full-grown larvae were seldom observed in the same mine. It was common for an individual larva to occupy several mines during its feeding period. The duration of the larval period ranged from 15 to 20 days, the average for 175 individuals being 17.6 days.

The mature larva is yellowish white, with the exception of the head, a portion of the first thoracic segment, legs and the anal shield which are black. It attains a length of about one centimeter. The body is somewhat flattened, and the segmentation is distinct. The second and third thoracic segments are wider than the first.

PUPAE AND ADULTS.—The pupae are reddish brown and somewhat resemble the mature larvae. Pupation occurs within the mine formed by the larva. The duration of the pupal period ranged, during 1937, from 7 to 12 days and averaged 9.6 days. The newly transformed adult is light yellow in color and has no black marking along the suture of the wing covers. It remains within the leaf for about two days, and during this time the characteristic coloration is acquired. When ready to emerge from the leaf, the adult eats its way through the epidermis. The beetles of the new brood are out in large numbers by the last of July.

The black locust, also called the yellow or common locust, is the preferred and most serious injured host plant. Early in the season, 1937, the overwintered beetles were observed feeding on the foliage of apple. The beetles in cages also fed on plum, mulberry, cherry, elm, wild crab apple, hawthorn, oak, soybean, honey locust and birch. In one instance, large numbers of the beetles of the new brood were found feeding on oak leaves. No eggs were found on any plants except black locust.

During the summer of 1937, there was only one brood of the locust leaf miner at Blacksburg, Va. The newly emerged beetles fed for about three weeks and then disappeared. First brood beetles which emerged in the insectary did not deposit eggs when confined in rearing cages, and no mating was observed.

On May 22, three small locust trees six to eight feet high were sprayed with lead arsenate, 3 pounds to 50 gallons of water, 12 ounces of fish-oil soap being used as a sticker. The application was repeated June 1. The spray apparently repelled the adults to the extent that eggs were not deposited and feeding was largely prevented.

In the severe outbreak reported by Houser (1918) in Ohio in 1912 and 1913, the early foliage on the locust trees was killed by frost and the beetles attacked apple. The apple trees were protected from serious injury by applications of arsenate of lead and molasses.

On June 11, 1937, fifteen pairs of the beetles were caged on a potted locust plant previously sprayed with lead arsenate and molasses. One day later, 15 were dead, and all were dead within three days.

SUMMARY.—The first beetle emerged from liberation May 5, 1937, at Blacksburg, Va. The first eggs were deposited May 24. The incubation period ranged from 9 to 11 days, and the total life cycle ranged from 31 to 43 days in length. The insect was observed feeding on several species of trees and plants, but eggs and larvae were found only on locust leaves.

Arsenate of lead has been frequently recommended for the insect. It proved effective in preventing injury to apple foliage during a severe outbreak in Ohio. In these studies, two applications of arsenate of lead applied early prevented feeding and oviposition by the adults.—12-17-37.

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Studies on the Control of the Orchid Weevil*

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The orchid weevil, *Diorymerellus laevimargo* Champ., was first noticed in New Jersey about 1916 by Harry B. Weiss (1917) feeding upon various species of *Cattleyas* and *Dendrobiums*. Since then it has been recorded from a number of states and apparently occurs wherever orchids are grown.

The beetle is about one-eighth inch long and one-half as wide, shiny black and glabrous above. Each elytron has six sharply-cut, rather broad, deep, sparsely punctual striae on the disc, and another stria along the margin beneath. The punctures on the under surface of the body and on the legs each bear a minute whitish scale.

LIFE HISTORY.—The larval stage is a white, legless, curved or somewhat crescent shaped grub not more than three-sixteenth inch long when full grown. Eggs and pupae have not been observed. The young larvae feed in the new roots of the orchid plants but have never been found abundantly. Their feeding results in the hollowing out of the inside roots and causes the tips to turn black and to die.

The beetles apparently spend most of their time hiding in the peat near the top of the pots, in the curled up basal part of the leaf or in the sheath surrounding the flower stalk. They do not crawl down into the peat to a depth of much more than one inch. No evidence has been found to indicate that the beetles or larvae feed upon the peat.

The beetles feed to a slight extent upon the roots but the greatest injury occurs when they feed upon the young tender leaves, upon the sheath surrounding the flower bud or upon the petals of the flower before they open or just after they have opened. This feeding appears as small irregular holes, causing the sheath to rot and die or causing the bloom to open imperfectly. The injured blooms are not salable.

The complete life history and habits of the orchid weevil are not known. There appears to be one and possibly two broods a year as indicated by the abundance of the beetles.

MECHANICAL CONTROL.—The control measures practiced by orchid growers have consisted principally of examining the plants several times daily during the flower season and picking off the beetles. This method is time-consuming and expensive and, as most of the beetles hide in the peat has not been very successful.

PARADICHLOROBENZENE.—Experiments conducted by Hamilton (1931) and Hamilton & Henderson (1933) in the summer and fall of 1930 demonstrated that excellent control might be obtained by applying paradichlorobenzene crystals to the surface of the peat in which the plants were growing. These crystals should be sprinkled evenly over the top of the peat at the rate of one-half to one gram of paradichlorobenzene to each inch diameter of the pot in which the plants are growing. This treatment was used for several years in one of the largest orchid growing houses in New Jersey, reducing the beetles to the point where very few were found and practically no commercial injury occurred to the bloom.

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The orchid grower concluded after several years use that there was some injury to the plants. This may have been due to using excessive amounts of the paradichlorobenzene, treatment when the temperature was too high or possibly treatment of plants which had been weakened by forcing into bloom at the most profitable time. Because of this injury to the growing plants, other methods of control were looked for.

MISCELLANEOUS CHEMICALS.—At the time the experiments were conducted with paradichlorobenzene, many other materials were tested. Some of these consisted of solutions of nicotine, soap and water; pyrethrum, soap and water; carbon bisulfide emulsion; carbon bisulfide emulsion containing naphthalene; and lead arsenate in suspension in water. These materials were applied in such a way as to wet thoroughly the peat in which the plants were growing. The nicotine, nicotine and soap and pyrethrum and soap were not effective in killing the beetles even when used at strong concentrations. Solutions containing soap caused a poor condition of the peat, resulting in development of fungous growth and preventing the peat from drying out properly. The carbon bisulfide emulsion and carbon bisulfide emulsion containing naphthalene were fairly efficient in killing the beetles but were very toxic to the roots of the plants. The lead arsenate suspension in water was also toxic to the roots of the plants. Naphthalene flakes were toxic to the insect but not so effective as the paradichlorobenzene, apparently due to the slower volatilization of the crystals.

PYRETHRUM AND DERRIS DUSTS.—In August, 1936, a few preliminary experiments were conducted with concentrated pyrethrum dusts and concentrated derris dust applied to the surface of the peat. The pyrethrum dust was known as *Dry Pyrocide* and was manufactured by the McLaughlin Gormley King Company of Minneapolis, Minn. This *Dry Pyrocide* consisted of an alcoholic extract of pyrethrum dispersed upon clay so that the final mixture contained 40 per cent extractives and 5 per cent pyrethrins I and II. The mixtures tested consisted of (a) *Dry Pyrocide*, 1 part; inert C Clay, 1 part; and (b) *Dry Pyrocide*, 1 part, inert C Clay, 2 parts. The derris powder contained 3 per cent rotenone and approximately 15 per cent total extractives. The derris mixtures tested consisted of (c) derris powder, 1 part; inert C Clay, 1 part; and (d) derris powder, 1 part, inert C Clay, 2 parts. These tests show that the *Dry Pyrocide* was quite effective in killing the beetles when dusted upon them directly or when dusted upon the surface of the peat in which the beetles were hiding.

Further studies in the use of the pyrethrum dust and derris dust were conducted in August, 1937. Beetles were collected in the orchid house and placed upon peat tightly packed in flower pots. After the beetles had had an opportunity to crawl into the peat, the surface was dusted with various mixtures, as indicated in the accompanying tables.

The pyrethrum powder contained 0.9 per cent pyrethrins I and II and was finely ground. The *D.H.S.*, a pine oil activating agent, was supplied by the Hercules Powder Company of Wilmington, Del. The *Dry Pyrocide*, containing 2 per cent pyrethrins I and II, was obtained from the McLaughlin Gormley King Company of Minneapolis, Minn. The derris powder contained 4 per cent rotenone and approximately 16 to 18 per cent total extractives.

Results of some of the laboratory tests are shown in tables 1, 2 and 3.

These tests showed a decided superiority of the pyrethrum powder or the *Dry Pyrocide* extract over the derris powder.

Table 3 gives the results with the various mixtures consisting of pyrethrum powder, pyrethrum powder plus talc, *Dry Pyrocide* and *Dry Pyrocide* plus talc. The dust mixtures were applied at the rate of one-half gram of the powder for the four-inch pots and one-fourth gram of powder for the three-inch pots. The tests were started August 17 and an examination was made August 20, or approximately 72 hours after treatment.

The peat in the experimental pots was carefully examined and it is quite likely the number of beetles indicated as missing in tables 1, 2 and 3 were dead, but because of their small size and because their bodies were covered with dust they may have been overlooked. Live beetles were more easily found than were the dead ones. Because of this possibility that the

Table 1.—Beetles treated August 13 and examined 48 hours afterwards.

MATERIALS	NUMBER BEETLES					PER CENT KILL
	Treated	Dead	Affected	Not Affected	Missing	
1B Pyrethrum Powder (0.9% pyrethrins) +5% *D.H.S.*	15	5	5	4	1	33.3
3B Pyrethrum Powder (0.9% pyrethrins)	15	8	7	0	0	60.0
4B McLaughlin Gormley King *Dry Pyrocide* (2% pyrethrins), 50 parts Talc, 50 parts	15	14	1	0	0	93.3
5B McLaughlin Gormley King *Dry Pyrocide* (2% pyrethrins)	15	14	0	0	1	93.3
6B Derris Powder (4% rotenone)+5% *D.H.S.*	15	1	2	9	3	6.7
Check	15	0	0	15	0	0.0

Table 2.—Results of second test with same materials as those given in table 1.

MATERIALS	NUMBER BEETLES				PER CENT KILL
	Treated	Dead	Alive	Missing	
1A Pyrethrum Powder (0.9% pyrethrins)+3% *D.H.S.*	15	1	10	4	6.7
3A Pyrethrum Powder (0.9% pyrethrins)	15	8	4*	3	60.0
4A *Dry Pyrocide* (2% pyrethrins), 50 parts Talc, 50 parts	15	13	1*	1	86.6
5A *Dry Pyrocide*	15	15	0	0	100.0
6A Derris Powder (4% roetenone)+5% *D.H.S.*	15	2	13	0	13.4

* Beetles affected but not able to crawl.

Table 3.—Tests with pyrethrum powder and *Dry Pyrocide* powder on orchid weevils. Tests started August 17; beetles examined August 20. Fourteen beetles to each pot.

MATERIALS	NUMBER BEETLES				PER CENT KILL
	Dead	Affected	Alive	Missing	
3A Pyrethrum Powder (0.9% pyrethrins); ½ gram to 4″ pot	10	2	0	2	71.4
4A *Dry Pyrocide*, 50 parts; talc, 50 parts; ½ gram to 4″ pot	9	0	0	5	64.3
5A *Dry Pyrocide* (2% pyrethrins); ½ gram to 4″ pot	13	0	0	1	92.9
7A *Dry Pyrocide*, 25 parts; talc, 75 parts; ½ gram to 4″ pot	11	0	0	3	78.4
3B Pyrethrum Powder (0.9% pyrethrins); ¼ gram to 3″ pot	13	1	0	0	92.9
4B *Dry Pyrocide*, 50 parts; talc, 50 parts; ¼ gram to 3″ pot	12	0	0	2	85.7
5B *Dry Pyrocide*, ¼ gram to 3″ pot	14	0	0	0	100.0
7A *Dry Pyrocide*, 25 parts; talc, 75 parts; ½ gram to 3″ pot	13	0	0	1	92.8

missing beetles were killed by the treatment but were not found, the control of the various dusts would seem to be better than that indicated by the per cent kill.

Soon after the pyrethrum dusts or the *Dry Pyrocide* dusts were applied to the surface of the peat, the beetles were observed crawling around, the dust stuck to their legs, antennae, mouth parts and body. It is possible that the slightly greater effectiveness of the *Dry Pyrocide* dust over the pyrethrum dust may have been due to its finer particle size, which resulted in better covering of the beetles, and to the toxic principles on the outside of the dust particles, which permitted the

toxic materials to be more readily absorbed. The surface of the beetles' bodies appeared to be somewhat oily as indicated by the ready adherence of the dust materials and the lack of wetting with water sprays.

CONDUCTING THE TESTS.—Laboratory tests were conducted in a manner quite similar to the usual greenhouse application of dusts. No tests were conducted in the greenhouse, however, because the beetles became scarce at the time the laboratory tests were conducted.

Tests were conducted in the greenhouse on various sized orchid plants to determine if the dusts would have any injurious effect upon the peat, roots or foliage of the plants. Plants of the following size were treated August 18 and examined from time to time over a period of several weeks.

1. Two-inch pots each containing two or three plants from 1 to 2 inches tall.
2. Two-inch pots containing a single plant from 4 to 6 inches tall.
3. Four and one-half inch-pots containing plants 10 or more inches tall and with actively growing root tips.

The following materials were applied to each of the three sizes of pots indicated above.

1. Pyrethrum powder containing 0.9 per cent pyrethrins.
2. *Dry Pyrocide* 25 per cent, talc 75 per cent, the dust mixture containing 0.5 per cent pyrethrins.
3. *Dry Pyrocide* 50 per cent, talc 50 per cent, the dust mixture containing 1 per cent pyrethrins.
4. *Dry Pyrocide* without any diluent, the dust mixture containing 2 per cent pyrethrins.

The materials were applied at a rate equivalent to three times as much dust as was used in tables 2 and 3; that is, the equivalent of 1½ grams of the powders were applied to each four-inch pot.

The plants were examined from time to time and observations were made by the foremen in charge of growing the orchids. No injury was observed at any time to the roots of the plants, the foliage or the peat. The surface of the peat treated with pyrethrum powder developed a slight mold two or three days after treatment. This, however, was not objectionable and soon disappeared.

SUMMARY.—The laboratory tests conducted with the derris powder, pyrethrum powder and *Dry Pyrocide* showed that the derris powder was considerably less effective than the pyrethrum powder or *Dry Pyrocide*. The pyrethrum powder and *Dry Pyrocide* gave an excellent kill of the orchid weevils in laboratory tests conducted as applications would be made in the greenhouse. The use of either the pyrethrum dust or *Dry Pyrocide* is not expensive, is easy and less objectionable to apply than the paradichlorobenzene treatment and would seem to have no possibilities of injury to the plants or the peat.—12-17-37.

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Two Elm Scolytids in Relation to Areas Infected with the Dutch Elm Disease Fungus

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The Dutch elm disease, *Ceratostomella ulmi* (Schwarz) Buisman, was first discovered in this country at Cleveland, Ohio, in 1930, and not until 1933 in New Jersey. Studies conducted cooperatively by both plant pathologists and entomologists working in Europe and the United States have shown that the occurrence of the disease is correlated with the occurrence of the elm bark beetles. The smaller European elm bark beetle, *Scolytus multistriatus* Marsham, was first

reported in this country in 1909 by Chapman,* at Cambridge, Mass. The native elm bark beetle, *Hylurgopinus rufipes* (Eich.), has long been known here.

THE INSECTS AS VECTORS.—*S. multistriatus* is by far the most important insect vector of the Dutch elm disease in this country, as indicated by laboratory research and field observations. The adult beetles carry the disease organism and they inoculate the elm trees by feeding in the crotches of small branches or by boring through the bark to the xylem in their attempts to make brood galleries. Adults of *H. rufipes* that are contaminated with the disease fungus likewise inoculate elm trees when these insects attempt to bore through the bark to make brood galleries; in addition, they may effect inoculation through their habit of hibernating in the bark of living trees, since the hibernating beetles sometimes bore through the bark into the xylem, and infection may take place during this process.

Since these two bark beetles are associated with the spread of the Dutch elm disease fungus, measures for their control are being carried on by the Bureau of Entomology and Plant Quarantine, with field headquarters at Bloomfield, N. J. In order that the most effective eradication measures for the disease may be utilized, it is necessary to do considerable scouting for the two elm bark beetles. In this work the division handling eradication and the Morristown, N. J., research laboratory of the same Bureau have cooperated closely. Others who have contributed to make the records as complete as possible are: Research workers of Cornell University located at Boyce Thompson Institute, Yonkers, N. Y.; the agricultural experiment stations of Massachusetts, Connecticut, Rhode Island and New Hampshire; and the New Jersey Department of Agriculture.

EARLY RECORDS OF *S. multistriatus*.—The earliest records we can find of the taking of *S. multistriatus* near New York, N. Y., or Philadelphia, Pa., were furnished by M. W. Blackman from records and specimens to which he had access in Washington, D. C. These were as follows: Hillsdale, N. J., 1924, collected by Quirsfeld; Millburn, N. J., 1926, collected by F. M. Schott; Long Beach, Long Island, N. Y., 1926, collected by A. Nicolay; and Stamford, Conn., 1930, collected by E. P. Felt.

From these data it will be noted that the earliest record of its occurrence in the vicinity of New York City is 1924, in northern New Jersey, and that this is closely followed by another record from a segregated locality in the same state, and by others from Long Island and Connecticut. This would indicate that the species may have been established in this area 10 or more years before 1924.

PRESENT DISTRIBUTION OF *S. multistriatus*.—The distribution of the smaller European elm bark beetle, *S. multistriatus*, with reference to the major area infected by the Dutch elm disease fungus in New York, New Jersey and Connecticut extends about 145 miles north of New York City to Quaker Springs, N. Y., and to Great Barrington and New Marlboro in southwestern Massachusetts. (This species was reported from Westfield, Mass., but a later scouting of the area failed to find it.) It also extends from New York City into Connecticut, reaching New Canaan, New Hartford, Avon, Glastonbury, Middletown, Durham and Madison. This bark beetle has been found on Long Island as far as Bay Shore, or about 40 miles east of New York City.

S. multistriatus is also found in the southern counties of New York to Narrowsburg, which is 75 miles northwest of New York City. It is found through all the counties of northern and central New Jersey to Woodstown in Salem County on the south, or about 90 miles south of New York City. A natural barrier, due to almost total absence of elm, exists in parts of several counties of southern New Jersey, this area being included in the pine-oak region. Northern Delaware and eastern Pennsylvania, as far west as Thomasville, Harrisburg, Mexico, Lewistown, Sunbury, Wilkes-Barre, Kingston, Osterhout, Sterling and Stroudsburg are also included in this large area extending across New Jersey from New York City.

* J. W. Chapman first found *Scolytus multistriatus* in the United States at Cambridge, Mass., in October, 1909 (1910, Psyche **17**: 63–8, Illus.). In October, 1911, Bussey Institution of Harvard University published an article by Mr. Chapman entitled, "The Leopard Moth and Other Insects Injurious to Shade Trees in the Vicinity of Boston." In this article he stated that, since working out the distribution of the insect in Massachusetts, he had found a piece of elm bark with a gallery and female of *S. multistriatus* in the laboratory of Dr. J. S. Kingsley at Tufts College, Medford, Mass. The piece of bark had been in Dr. Kingsley's possession for more than seven years and came from an elm tree on the campus of the college. Mr. Chapman further wrote, "We have no way of telling how much longer the beetle has been in this country but from the damage accomplished it had probably been here many years previous to that time."

S. multistriatus occurs in eastern Massachusetts; also in southern New Hampshire (North Hampton), approximately 50 miles from where it was first discovered in Cambridge, Mass., in 1909. It has spread about 40 miles southeast to Plymouth, Mass., and 20 miles west to Sudbury, Mass. This bark beetle also occurs in the southwestern part of Massachusetts, but this infestation is connected with the large territory that was presumably first infested in or around New York City and possibly additionally in one or more points in the Hudson River Valley.

The first introductions and establishments of the species appear to have been near large seaports—New York, Boston and possibly Philadelphia. Burl elm logs and elm sticks used for crating material are known to have been received from Europe at these and other ports on the eastern seaboard previous to the enforcement of a quarantine in 1935. Some of this material is known to have been infested with *S. multistriatus*. Parts of these shipments in turn were destined to inland cities, being carried from ports of entry over well-known railroad routes. Infestations have originated along or near such routes, such as the Baltimore and Ohio Railroad in the Potomac and Ohio River Valleys, over which it is known that logs were shipped from Baltimore, Md. In some cases the beetles escaping from the logs en route were apparently contaminated with the causative organism of the Dutch elm disease. There is some reason to believe that the infestation in the Hudson River Valley region above Orange and Putnam Counties, N. Y., and adjacent territory in northwestern Connecticut and southwestern Massachusetts was started by noninfected beetles, since, after much scouting, no trees infected with the fungus have been found in this area. It is also possible that the upper Hudson River Valley region may have become infested by means of natural spread from beetles that first became established around New York City some years before the first introduction of the Dutch elm disease fungus in the same region. It may be assumed that this condition applied when the original infestation was started in the Ohio River Valley of West Virginia and Ohio. The first finding of beetles around Parkersburg, W. Va., was made in 1936. After some scouting, however, it was estimated that 10 or more years had passed since the first establishment of the beetle in that region.

Field scouts looking for symptoms of the Dutch elm disease in the Ohio River Valley region in 1936 found *S. multistriatus* at Parkersburg, W. Va. Subsequent scouting for evidence of the beetle that year and in 1937 showed that it was well established in a large contiguous territory comprising parts of West Virginia, Ohio and Kentucky. Heavy infestations were found in some cases, especially in the Ohio River Valley. The infestation extends almost continuously along the Ohio River and to each side of it from Short Creek just south of Wellsburg, W. Va., to Louisville, Ky., with findings also at Cloverport and Henderson, Ky. It's known most northern point of distribution in Ohio is East Liverpool near the Ohio River, and it was taken at a distance from the river in the same state at Salineville, Cadiz, Freeport, south of Byesville, west of Zanesville, north and south of Logan, at Wellston, Waverly, south of Jasper and at Dunkinsville, Ohio. It was also taken at Ripley, Nicholsville and Cincinnati, Ohio, near the river.

Beetles or galleries were also taken at Madison, Rockport and Evansville, Ind., these being points along the Ohio River. Evansville, Ind., and Henderson, Ky., are the westernmost points of distribution known at this writing.

An area of approximately 225 square miles was found infested south of Pittsburgh, Pa., and, so far as a quick scouting of the region revealed, this was not connected with the major area along the Ohio River which extends southward from near Wellsburg, W. Va. The area in Pennsylvania is about 20 miles distant, but it might prove to be connected if more scouting were done in that section.

S. multistriatus is also established in eastern West Virginia, five locations having been found in Jefferson and Berkeley Counties. The species was also found at Antietam, Washington County, Md., which is across the Potomac River from Jefferson County, W. Va. These latter points are only 15 to 20 miles west of Brunswick, Md., where three elm trees infected with the Dutch elm disease were located and removed in 1936. *S. multistriatus* was not found in the immediate vicinity of Brunswick, Md.

DISTRIBUTION OF *H. rufipes*.—*H. rufipes* occurs in Canada and in the northeastern, southeastern and central parts of the United States. It has been taken as far south as Decatur, Ala., and Yazoo City, Miss.; as far west to Kansas City, Mo., and Lawrence, Kan. There is reason to believe that it occurs over most of the range where elm trees grow. Beetles or galleries have been taken in all the counties and outlying cities of this country where trees infected with the Dutch elm disease have been found. So far as has been determined, this species is the only known insect vector occurring in the following outlying points where trees infected with the Dutch elm disease have been found and removed: Cleveland, Ohio; Indianapolis, Ind.; Cumberland, Brunswick and Baltimore, Md.; Norfolk, Va.; Wileys Ford, W. Va.; and Old Lyme, Conn. Athens and Cincinnati, Ohio, Branford and Guilford, Conn., should be added to the list of outlying infected areas, but here both species of bark beetles have been encountered. In the major area infected with the Dutch elm disease both species of bark beetles occur, with varying abundance, dependent upon the abundance of elm and the general condition of the trees.

DISTRIBUTION OF DUTCH ELM DISEASE.—The major area infected with the Dutch elm disease fungus, outlined on the map, fig. 1, includes the following:

Connecticut.—Fairfield County (with isolated trees found in Branford and Guilford in New Haven County).

New York.—Parts of Orange and Putnam Counties and the whole of all counties to the south of these. Kings, Queens and Nassau Counties, and Huntington Township in Suffolk County on Long Island are included.

New Jersey.—All or parts of the counties in northern and central New Jersey as far south as the northern parts of Mercer and Monmouth.—12-17-37.

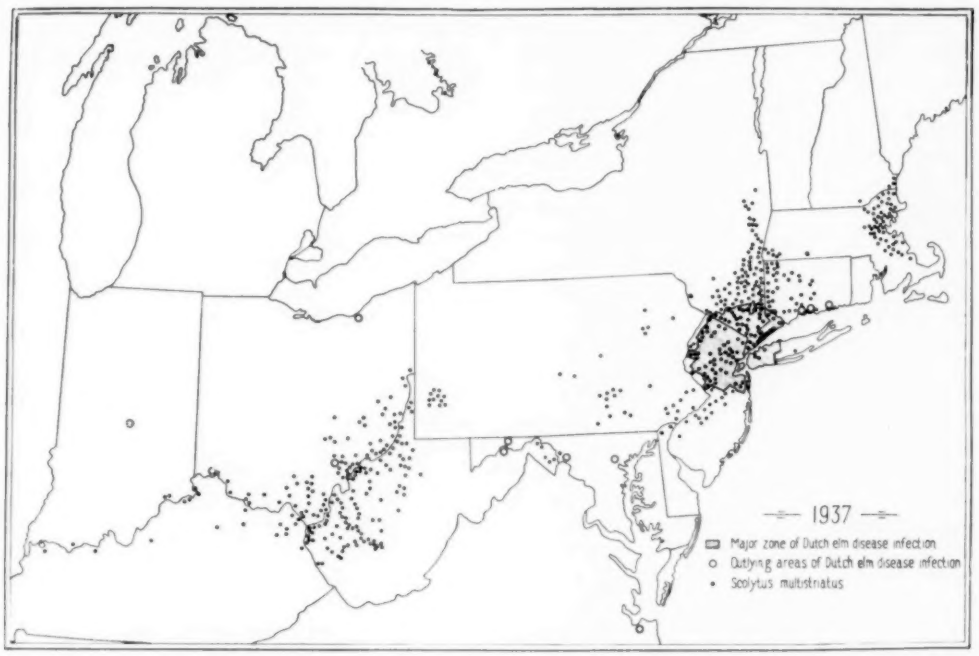

FIG. 1.—Map showing known distribution of the Dutch elm disease fungus and *Scolytus multistriatus* in the United States. *Hylurgopinus rufipes* also occurs in these and many additional states as well as in Canada.

FUNGOUS DISEASES of rose plants are the subject of an Oklahoma quarantine placed in December on the entry of Texas rose bushes which are required to be inspected at digging time and sprayed.

Feeding Habits of *Scolytus multistriatus* Marsham with Reference to the Dutch Elm Disease

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Its characteristic habit of feeding in the crotches of elm twigs is responsible for the importance of *Scolytus multistriatus* Marsham as the principal insect vector of the Dutch elm disease organism in the United States. Any consideration of spraying as a possible control measure involves the feeding-wounds made by the beetle. It is logical that a more thorough knowledge of its feeding habits might also contribute to a better understanding of its flight tendencies and furnish information pertinent to the sanitation measures already under way for reducing beetle population.

It is the purpose of this paper first, to suggest criteria for the systematic study of *S. multistriatus* feeding-wounds; second, to attempt an analysis of possible reasons for the apparently erratic distribution of beetle-feeding in the hope that the factors which influence the choice of beetles for particular trees can be determined; and, third, to show how such information may be applied in the execution and evaluation of the control measures that have been used or suggested.

CRITERIA FOR STUDY OF FEEDING-WOUNDS.—From data taken in 1934 and 1935 by Dr. P. A. Readio, and from other data taken in 1935, 1936 and 1937 by the writer, figures pertaining to the occurrence of feeding-wounds in the Bronx and Westchester County in New York state were assembled. Samples were cut from 385 trees, representing most of the conditions under which elms were found growing in those areas. The sample branches ranged from 5 mm. to 15 mm. in diameter. The number of crotches was on the average directly proportional to the diameter of the sample, but with a sufficient number of samples it was found that any one diameter might encompass nearly the entire range of the number of crotches occurring on the smallest to the largest samples.

The percentage of crotches attacked and the number of wounds per sample varied independently, and each varied independently of the diameter of the sample and of the number of crotches per sample. This was taken to mean that with a moderate amount of feeding, sample elm branches within reasonable diameter limits may receive *S. multistriatus* feeding wounds in varying numbers, but that the amount of feeding per sample is independent of the number of crotches and of the size of the sample.

In this paper references to wounds always indicate wounds made during the period of beetle activity immediately preceding the examination of the samples. "New" as applied to crotches refers to crotches formed by the union of a twig of the current season's growth with older growth.

A factor which might have influenced the choice of branches for feeding is the relative numbers of "new" and "old" twigs and shoots with consequent differences in the diameter of the twigs composing the crotches. Reference to the data, however, indicates that this factor need be considered only in exceptional instances. A scatter diagram indicated that on individual samples there was no correlation between number of wounds and number of new or old crotches, and no correlation between number of wounded new crotches and total number of new crotches. There was, of course, the obvious correlation that in heavy infestations the majority of wounds occurred on whatever age of crotch predominated.

When the feeding was very heavy the number of wounds was naturally restricted by the number of crotches. Ordinarily, in view of the data gathered it would seem well to refer to the number of wounds per sample rather than to a percentage. For example, wounding to the extent of 50 wounds per unit of tree gives an equal chance for infection, and indicates the presence of the same number of beetles, whether there are 100 or 500 crotches on the sample. In the examples given, the percentages of wounding would be expressed as 50 per cent and 10 per cent, respectively, both numbers actually referring to the same number per larger unit.

In the field, more than 2 or 3 wounds

per sample was on the average a rather high figure. An average of 5 wounds per sample may be taken as indicative of a "medium-heavy" infestation, and any number over 10 may be taken to indicate wounding in considerable excess of the average amount.

ERRATIC DISTRIBUTION OF FEEDING-WOUNDS.—Of the 385 trees from which detailed data were taken in the field, only 152, or 39 per cent bore feeding-wounds. Of the total of 3423 wounds recorded, 87 per cent were on 32 per cent of the trees. In 1935 and 1936 the data were taken from trees located in the midst of the heavily infected Dutch elm disease area in Westchester County, N. Y., and in the Bronx, where *S. multistriatus* was known to be generally distributed.

From the earlier data, only very general inferences can be drawn. It is apparent that the occurrence of feeding-wounds in the field is so variable that random sampling was not very productive. Only by accident were trees found bearing a large number of wounds. In some instances all the trees sampled in a given area had wounds; in other localities some trees had no wounds, some had few and some had many. It appeared that sometimes beetles were attracted to certain limited areas where they fed indiscriminately, and that at other times they were attracted to certain trees out of a large number of possible choices. It was reasonable to assume that with the general occurrence of beetles throughout the area there must be some basis for the apparent selection of trees upon which to feed, but there was in the data only one tangible suggestion in this direction; namely, the accidental finding at one location of a tree where beetles had been attracted for entry to dead wood and had fed upon the twigs of the same tree. This tree was found in the fall of 1936.

In 1936 very few current season feeding-wounds were found east of the Hudson, possibly a reflection of the sanitation measures which by that time had been extensively employed in Westchester, the Bronx and Putnam County. In 1937, therefore, it was decided to make extended observations in the outer portions of the disease zone in Orange County, where fewer diseased trees had been found, and where sanitation had not yet been completed.

INFLUENCE OF DEAD WOOD.—When diseased tree No. 50109-E near Washingtonville on the northern edge of the infected zone in Orange County was cut down it was found to have considerable dead wood with galleries containing well-grown larvae of *S. multistriatus*. Recent feeding wounds were numerous on the tree. On a 20-inch tree a few feet from the diseased tree, 5 samples bore 11 wounds. A few feet from this tree one of about the same diameter had 20 wounds on 5 samples. Within a radius of a quarter mile, 16 trees of diameters ranging from 8 to 30 inches were sampled, 5 to 7 samples being taken from each tree. Only 7 of these trees had wounds, and these at the rate of 1 to 4 wounds per sample.

In an open field one mile from the diseased tree mentioned was a 24-inch tree that had been struck by lightning some time shortly before the first of June. This tree was found on July 31. One of the two main leaders was split away from the trunk at a height of about 10 feet and was lying on the ground with its proximal end still attached to the trunk by splinters. The branches of this lightning-struck portion contained a large number of galleries of *S. multistriatus*, with larvae of all stages, prepupae and pupae. The crotches on the lightning-struck portion were not wounded, but samples taken at random from the living portion bore an average of 36 recent wounds per sample. In a total of 773 crotches there were 540 wounds. On several samples every crotch was wounded. Some of the wounds had begun to heal but most of them were still open, indicating a comparatively recent origin.

The beetle-breeding wood was destroyed as soon as possible, but a few specimens had probably emerged; several beetles were noted in freshly made wounds shortly after the wood had been removed. From the fact that there were no wounds on the lightning-struck portion it was inferred that the beetles had not been attracted to the tree for feeding purposes until after it had been struck and the struck portion had become suitable for beetle entry. It was further indicated that some of the few beetles which emerged from the fallen portion before it was destroyed had fed upon the living portion.

KEY TREES.—After these observations at Washingtonville, the plan followed was to sample trees containing dead wood or

trees near a dead tree and to select trees at different distances from these key trees for taking additional samples for comparison. The accompanying diagrams and data relative to two of the locations examined will give an idea of the nature of the data obtained.

In figs. 1 and 2 the key trees are represented by circles with crosses. Individual trees are designated by black dots. A number at a black dot indicates the number of feeding wounds per sample on that tree. Approximate distances from sampled trees to key trees are also indicated, these distances not necessarily being correctly proportioned on the charts. Since diameter of trees and relative vigor appeared not to be correlated with number of feeding wounds, the various trees sampled are not described. The diameters varied from 6 inches to 38 inches.

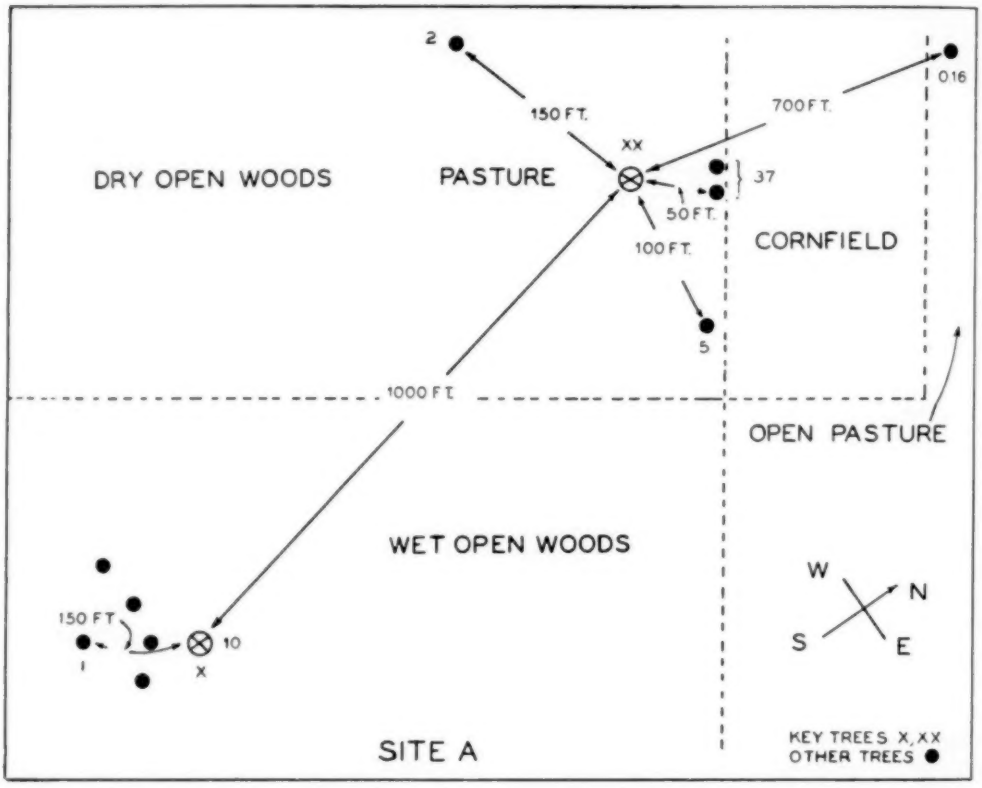

FIG. 1.—Site A, Minisink Township. Key trees, *x* and *xx*. *Tree x:* an 18-inch diseased tree, no. 39326-E. Old *S. multistriatus* galleries occurred in one old dead leader. A more recently dead branch contained galleries with well-grown, living larvae. *Tree xx:* a 14-inch dead tree. Contained many *S. multistriatus* galleries with well-grown living larvae. Number of feeding-wounds per sample on a tree is indicated by a numeral beside the black dot representing that tree.

The examples given indicate the type of observations made at the selected locations, and the consistent nature of the records made. In addition to the sites described, other areas at or near Chester, Washingtonville, Monroe, Harriman, Crystal Run, Cornwall, Mountain Valley, Middletown, Westtown and Cuddeback-ville, and individual trees along the highways between Newburgh and Port Jervis and between Warwick and Newburgh were investigated. In every instance, trees located relatively near what might be termed "beetle-wood," and trees in which such wood occurred had the largest number of feeding wounds, and usually trees located only a comparatively short distance from this wood bore very few wounds or none at all.

It is significant to note that the presence of dead wood alone in or near the

trees was not in itself correlated with feeding activity. In order to have an influence on feeding, the wood apparently had to be in such condition as to be either producing or attracting beetles sometime during the season when the feeding occurred. On several occasions when trees were examined because of the presence of two control measures most commonly mentioned in connection with *S. multistriatus* and the Dutch elm disease, namely, sanitation and spraying. It would appear to be of importance to destroy as soon as possible injured, dying and dead limbs, not only to eliminate breeding places, but also to destroy the material

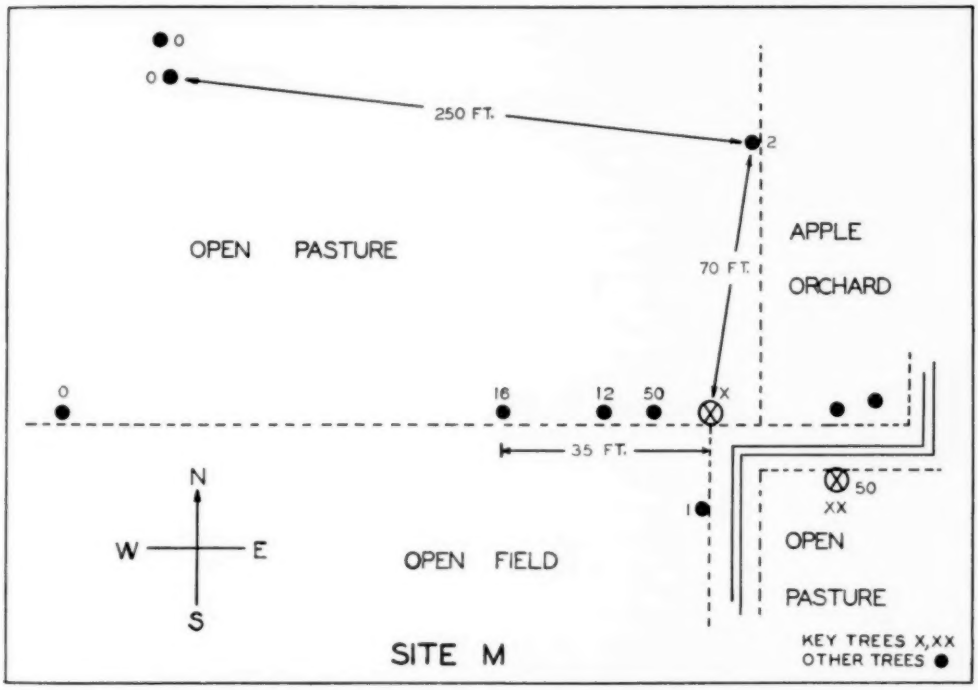

FIG. 2.—Site M, Montgomery. Key trees *x* and *xx*. *Tree x:* a 16-inch tree that had been broken off, probably struck by lightning, at a height of about 10 feet. Many galleries and well-grown larvae of *S. multistriatus*, together with exit holes, in the fallen portion. Tree was located a few feet from road at the corner of an open pasture. Dead portion had fallen to northwest and was lying in the corner of the pasture. *Tree xx:* a 30-inch tree with several 6-inch to 10-inch dead branches. *S. multistriatus* galleries in dead branches. Beetles had probably all emerged. Number of feeding-wounds per sample on a tree is indicated by a numeral beside the black dot representing that tree.

large dead limbs, no wounds were found, and examination of the dead material revealed that the wood had been beyond the attractive stage for some time and that it had never harbored any beetles. In some instances where wood containing beetle larvae was found, it appeared that feeding had been done on neighboring twigs before the beetles entered the oviposition wood. At other times it appeared that beetles emerging from dead wood fed immediately on the twigs in the vicinity.

CONTROL MEASURES.—The data presented have a certain amount of significance when considered with respect to the that may be an important influence in attracting beetles to a certain area for feeding.

The rôle of spraying as one of the means of attack against the insect vectors of the Dutch elm disease organism, whether in the form of a poison, as a repellent or as a fungicide to prevent infection through spores already introduced into feeding-wounds, is still uncertain. As was shown above, different trees in the same area vary through all possible degrees of susceptibility to beetle attack, and there is no basis for even guessing whether sprayed trees would or would not have been at-

tacked had spray not been applied. It may be that if the susceptibility of trees with suitable dead wood to beetle-feeding can be established with greater certainty it will be possible to select several large potentially favorable trees and divide each into several spray plats. In this idea, additional difficulties are at once apparent, one important one being that when such wood is discovered it is usually too late, or, if not too late, the wood should at once be destroyed.

Spraying relatively small trees in large or small cages where a known supply of beetles can be introduced has appeared to offer experimental possibilities, and several hundred trees have been used in this way. There is no doubt as to the fact that lead arsenate, for example, is toxic to the beetles, but whether it will prove to be sufficiently toxic in a sufficiently short time requires further study.

It has appeared that in general there was less feeding on sprayed trees than on unsprayed trees, when a certain known number of beetles was caged on each tree, and that under such conditions the wounds made on sprayed trees seemed to be shallower. But when trees treated with different amounts of spray material, together with unsprayed trees, were placed in a large cage, and beetles allowed a free choice, variations in the amount of feeding occurred irrespective of the sprays, and seemed to depend more on the relative positions of the trees in the cage. Although the data on these experiments have not yet been properly evaluated, the significant point to be made here is that a heavy coating of spray on many trees did not always lessen the amount or severity of feeding. The entire problem, including the use of fungicides in the sprays, is receiving further study.

SUMMARY AND CONCLUSIONS.—A criterion for the systematic study of the feeding habits of *Scolytus multistriatus* has been suggested; namely, the use of number of crotches per sample as a basis of comparison.

There is extreme variation in the range and extent of feeding by *S. multistriatus*. Observations made on more than 500 trees, including the examination of more than 100,000 crotches lead to the inference that the presence of wood which is either attracting or producing beetles in or near a given tree renders that tree more favorable for feeding attacks.

The exact value of spraying as a control measure against *S. multistriatus* remains in doubt, but it is increasingly indicated that the destruction of injured, dying and dead elm wood should not only aid materially in the control of the beetles by destroying their breeding places, but also should aid in reducing the spread of the disease by rendering healthy trees less subject to feeding attacks by possibly contaminated beetles.—12-17-37.

Japanese Beetle Field Control Tests in Delaware

HARRY F. DIETZ[1] and ROGER L. PIERPONT[2]

The purpose of these experiments was to determine the relative efficiency of several combinations[3] of ground derris and of certain synthetic organic compounds in combination with several adhesives as foliage protectants against the ravages of the Japanese beetle, *Popillia japonica* Newm. Fleming & Metzger (1936a) proposed the use of 3 pounds of ground derris, having a 4 per cent rotenone content, and 3 pounds of a 50 per cent rosin residue emulsion made according to the formula first suggested by Goodhue and Fleming (1936). Guy (1937) and Guy and Schmitt (1937), reporting experiments with certain thiuram sulfides and phenothiazine, concluded that tetramethyl thiuram disulfide (4 pounds) plus 1 pint of a 40 per cent rosin residue emulsion gave the best protection against Japanese beetle attack, but considered derris combined with rosin residue emulsion (50 per cent) almost its equal in efficiency. No quantitative ratings were given.

Lead arsenate (6 pounds) with 4 pounds of wheat flour is a standard control on many plants (Fleming & Metzger 1936b),

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The arrangement of the author's names is alphabetical, denoting neither seniority nor precedence.

[3] The composition of mixtures mentioned in this paper is based on 100 gallons of water.

as is hydrated lime (20 pounds) with 3 pounds of aluminum sulfate (Metzger & Lipp 1936). These treatments are open to considerable objection. It is a well-known fact that hydrated lime has the conspicuous fault of building up heavy and unsightly deposits on ornamental plants and on fruit, as well as staining paints, brickwork, walks and various garden structures unless suitable, often cumbersome and expensive methods are taken to avoid such occurrences. Furthermore, it has been shown previously by many investigators that lead arsenate at the high and unbuffered concentrations at which it is thus used has the disadvantage of causing severe plant injury and, in certain cases, the death of both commercial and ornamental varieties of peach and plum. Although high concentrations are tolerated by apples and grapes, if buffered by such a fungicide as Bordeaux, there is nevertheless a residue removal problem of considerable importance.

TEST ORCHARD.—For these tests, the same orchard used by Guy and Schmitt (1937) was selected because of its location in the midst of an area of heavy infestation, because of its size (four and one-half acres), and because of the number of both peach and apple varieties it contains. Five varieties of apples are interplanted with eight varieties of peaches, the ripening periods ranging from early midseason (Alton) to very late fall (Krummel). Such conditions tend to reduce the variation in feeding habits, pointed out by Smith (1923) as an important factor influencing the control of this pest. This orchard is located between Yorklyn and Centerville, Del., and occupies the crest and gentle northern slope of a low ridge. Its surroundings were as follows: There was a large wheat field in the valley to the north, a woodland to the east, a large planting of soybeans to the south and a large alfalfa field to the west. The orchard was exposed to attack from three sides, therefore, during heavy migrations of the beetle.

SEASONAL INFLUENCES.—The season of 1937 was a variable one. Frequent and heavy rains occurred throughout the entire period of beetle activity. Periods of very high relative humidity, usually above 50 per cent, and of high temperatures above 90 degrees F. rapidly alternated with very cool and cloudy ones. These conditions were directly reflected in the activity of the insect. At the time of usual emergence late in June, a cool period interfered so that the first heavy emergence in 1937 was about one week later than that in 1936. Shortly after the first application of control treatments (July 7–9), there was a week of cool weather. This in turn was succeeded by a prolonged period of the hottest weather of the summer, during which time the second protective spray treatments were applied. As a result of these conditions, there were two pronounced migrations of the beetles, the largest being on July 24 just after the application of the second spray was finished. Roving of the beetles throughout the season was marked, and the anomalous and inconsistent feeding reactions recorded by Smith (1923) were confirmed. Beetle activity ceased suddenly in early August, making a third application unnecessary. A third spray was applied, however, in the case of treatments 3, 4, 6 and 7, treatment 2 being left as a control and treatment 6 being a replication of treatment 1.

The frequent rainfall had a marked influence upon the phytocidal effect of the standard lead arsenate sprays applied to the peaches for plum curculio control. Considerable arsenical injury resulted, which made the peach foliage more attractive to the beetle on account of its yellow chlorotic color.

TEST METHOD.—In general, the test method used was the same as that employed by investigators of the U. S. Bureau of Entomology and Plant Quarantine, and also by Guy and Schmitt, namely the treatment of large, unreplicated blocks of trees. Such procedure avoids the effect of the selection by the beetles of preferred trees, even of the same variety, on the performance of any treatment. The test plots were 3 trees wide and from 10 to 12 trees long.

Frequent observations, usually at two-day intervals, were made by one or both of the authors. The varieties, Alton and Krummel peach and Starking, Rome and Golden Delicious apple, the foliage of all of which seemed equally susceptible to attack, were chosen for this purpose. The time of the sprays was based on these observations.

The first application of treatments was made immediately after invasion of the orchard was observed; in other words, be-

fore any concerted attack on the trees had occurred. This is important, as was pointed out by Safro (1929). The second application was made as soon as any invasion of the better treatments was noted. The following method was used in evaluating the results. The amount of beetle feeding was rated in five categories; none, 0; very light, 1; light, 2; moderate, 3; and heavy, 4. The number of trees in each

Table 1.—Composition of sprays tested for protecting foliage against the Japanese beetle.

Treatment No.	Materials	Composition per 100 Gal. Water
1	Tetramethyl thiuram disulfide	2½ lb.*
	Rosin residue emulsion	1 lb.†
2	Tetramethyl thiuram disulfide	1½ lb.
	Flotation sulphur paste (60 per cent sulfur)	2 lb.
	Rosin residue emulsion	1 lb.
3	Tetramethyl thiuram disulfide	1¼ lb.
	Phenothiazine	1¼ lb.
	Rosin residue (10 per cent special)	2 lb.
4	Tetramethyl thiuram disulfide	2½ lb.
	Sulfated fatty alcohol and synthetic adhesive	2 fl. oz.
6	Tetramethyl thiuram disulfide	2½ lb.
	Rosin residue emulsion	1 lb.
	(A replication of Treatment 1 applied 3 times)	
7	Tetramethyl thiuram disulfide	1¼ lb.
	Derris	1¼ lb.
	Rosin residue emulsion	1 lb.
10	Phenothiazine	3 lb.
	Rosin residue emulsion	1 lb.
11	Hydrated lime	20 lb.
	Aluminum sulphate	3 lb.
12	Ground derris	4 lb.
	Rosin residue emulsion	4 lb.
13	Tetramethyl thiuram disulfide	5 lb.
	Rosin residue emulsion	1½ lb.
14	Ground derris	4 lb.
	Rosin residue emulsion (special)	4 lb.
15	Hydrated lime	20 lb.
	Rosin residue emulsion	4 lb.
16	Hydrated lime	20 lb.
	Menhaden fish oil	1½ pt.

* Tetramethyl thiuram disulfide refers to a compound containing 80 per cent active ingredients and 20 per cent inert ingredients.

† Rosin residue emulsion, unless otherwise noted, refers to the Goodhue-Fleming formulation.

category was multiplied by the number of the category and the sum of the products added together was then divided by the total number of trees. The final figure thus obtained may be termed the performance rating. This system of scoring is similar to that used in determining certain scholastic ratings and is an inverse rating.

Of 16 treatments applied, 13 of particular interest are listed in table 1. All materials were applied at a gauge pressure of from 350 to 375 pounds. A single nozzle spray gun was used, and particular pains were taken to secure thorough coverage of both the upper and under surfaces of the leaves as well as the fruit. Excessive run-off was avoided.

Discussion of Results.—From the results given in table 2, it will be noticed that the number of trees used in the several treatments is not uniform. This was due to variation in the width of the orchard and to peach trees missing in the different blocks. The possible error that may have been thus introduced does not invalidate the obviously large differences that exist between some of the treatments or groups of treatments. The most highly protective material is one by the use of which the largest number or the highest percentage of trees remain free from any or but little feeding injury throughout the season. Therefore, the first category of feeding injury, namely none, may be considered the most important measure of the validity of the performance rating.

The results obtained show clearly that five treatments were the most effective; *i.e.*, treatments 1, 6, 10, 12 and 13. These are, respectively, tetramethyl thiuram disulfide compound, 2½ pounds, and rosin residue emulsion (Goodhue-Fleming), 1 pound, applied twice and three times;

Table 2.—Results of treatments to protect foliage against the Japanese beetle.

Treatment No.	No. of Trees	Extent of Injury Categories					Rating
		0	1	2	3	4	
1	28	15	11	1	1	0	0.57*
2	25	7	8	4	5	1	1.40
3	23	3	9	5	4	2	1.69
4	23	3	11	5	3	1	1.47
6	24	12	10	1	1	0	0.62*
7	22	6	10	5	0	1	1.09
10	25	13	8	4	0	0	0.57*
11	27	4	9	8	6	0	1.59
12	25	14	8	2	1	0	0.67*
13	27	22	5	0	0	0	0.17*
14	29	12	9	6	1	1	0.96
15	33	1	17	13	2	0	1.49
16	34	2	6	11	6	9	2.41

* Best treatments.

phenothiazine, 3 pounds, and rosin residue emulsion (Goodhue-Fleming), 1 pound; ground derris, 4 pounds, and rosin

residue emulsion (Goodhue-Fleming), 4 pounds; and tetramethyl thiuram disulphide compound, 5 pounds, and rosin residue emulsion (Goodhue-Fleming), 1½ pounds. These results confirm those of Guy and Schmitt (1937) with regard to the high efficiency of tetramethyl thiuram disulphide and derris. The results obtained with phenothiazine appear to be somewhat better than those reported by Guy and Schmitt. This raises the question as to the effect of mass protection, since the phenothiazine treatment was placed between two effective treatments. On the other hand, the plot with 2½ pounds of tetramethyl thiuram disulphide in two applications was adjacent to the poorest of all treatments—hydrated lime and fish oil. On the other side of the hydrated lime and fish oil plot was hydrated lime in combination with a (Goodhue-Fleming) rosin residue emulsion. It would seem, therefore, that mass protection is effective only when a relatively good product is employed. The actual performance of any material, then, should be determined not only by large block treatments, but also through the use of replications and possibly by exposed block treatments in which a specific compound is so placed that it is subject to no protection on any side.

The hydrated lime treatment did not compare favorably with the most effective treatments. The best of them was the hydrated lime and rosin residue emulsion (Goodhue-Fleming) combination proposed by Fleming and Metzger (1936b). None of the hydrated lime treatments should be used on peaches, for the reason that even with vigorous rubbing, it was impossible to remove the residue satisfactorily. On apples, however, the residue on the fruit disappeared to a considerable extent due to frequent and heavy rains, and what remained at harvest could be removed by brushing.

The influence of the adhesive used with any material is well illustrated by the following examples: with hydrated lime, fish oil was much inferior to any other adhesive, although the load applied was as good as with aluminum sulfate or with rosin residue. In fact, the fish oil may have acted as an attractant, since invariably within two days after an application was made the plot in question was always reinfested. Although the sulfated fatty alcohol containing a synthetic adhesive has proved very effective for other uses, in combination with tetramethyl thiuram disulphide it was inferior to the same product in combination with Goodhue-Fleming rosin residue emulsion. With derris, the Goodhue-Fleming formulation of rosin residue was superior in performance to the same concentration of derris plus an experimental rosin residue emulsion.

The substitution of tetramethyl thiuram disulphide with products which by themselves gave good performance did not result in any combination which was as effective as the five best treatments. The nearest approach to them in efficiency was the combination of tetramethyl thiuram disulphide and derris with Goodhue-Fleming rosin residue emulsion.

With regard to the additional protection afforded by a third application (in 1937), the results of treatment 1 and 6 are directly comparable. It will be noted that there is a very close agreement in the results obtained, although they were placed in fairly widely separated parts of the orchard. Since treatment 1 was adjacent to the poorest of the hydrated lime treatments, it appears certain that the third spray was of little or of no value and that the maximum damage to any tree occurred between the first application on July 7 and August 1.

CONCLUSIONS.—From these data it seems that ground derris and a tetramethyl thiuram disulphide mixture are at present the most effective materials as foliage protectants against the ravages of the Japanese beetle. Application should be made prior to any heavy invasion by this insect and the proper adhesive should be used.—12-17-37.

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Influence of Feeding Habits of *Tiphia vernalis* on the Parasitization of the Japanese Beetle

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Tiphia vernalis Rohwer, a parasite of grubs of the Japanese beetle (*Popillia japonica* Newm.), was first introduced into the United States from Chosen (Korea) in 1924 in the cocoon stage and in 1926 in the adult stage. The first field liberations were made in 1925 and recovery was first made in 1928. Since that time over 600 colonies, each consisting of approximately 100 females, have been placed in the Japanese beetle infested area in the northeastern part of the United States. Although these colonies have not all been surveyed as yet, there is evidence to show that over one-half of them have become definitely established and are increasing in numbers and spread.

This parasite is present in the field from the first of May until the latter part of June. The adults feed almost exclusively on the honeydew of aphids associated with the leaves of maple, cherry, elm and other trees and shrubs. Early in the afternoon, after the females have completed feeding, they burrow into the soil in search of host grubs on which to oviposit. After locating a host grub, the female *Tiphia* stings it in the mid-thoracic region, then proceeds to place an egg on the grub near the third thoracic and first abdominal segments. Although the sting paralyzes the grub only temporarily, it allows the female to oviposit freely without disturbance. The egg stage covers a period of about 1 week, and the larval stages cover about 3 weeks, depending, of course, upon soil temperatures. After the parasite larva has consumed the body contents of the grub it spins a cocoon, changes to the adult stage early in the fall, but remains in the cocoon until the following spring.

Observations of colonies of *T. vernalis* now established in the Japanese beetle area have shown that the adult parasites are attracted to and congregate on the leaves of various trese and shrubs which are infested with aphids, in order to feed on the honeydew exuded by them. It has also been observed that the host grubs in the areas near which *Tiphia* feed are usually more heavily parasitized.

SELECTION OF COLONY SITES FOR SURVEYS.—In 1935 and 1936, systematic surveys were made at two colony sites to determine the degrees of parasitization and of superparasitization of Japanese beetle grubs effected by this parasite near the area of concentrated adult feeding. The first colony, which was surveyed in 1935 and 1936, is in a pasture at Rushland, Pa. Parasites were liberated here in 1931, and the colony has shown a steady increase in numbers since that time. The second colony, which was surveyed in 1936, is located on a golf course at Philmont, Pa. This colony, the original parasites for which were liberated in 1927, has shown a remarkable build-up and spread since that year. Since 1932, approximately 35,000 adult females of *T. vernalis* have been collected at this site for colonization purposes, and in spite of this heavy drain the colony has increased in numbers and extended its area each year.

The site selected for the surveys at Rushland was at one corner of the pasture near a large elm tree heavily infested with aphids which attracted the *Tiphia* from the surrounding area. The site at Philmont was at one side of the golf course near a row of fairly large maple trees, on which the *Tiphia* congregated for feeding on the honeydew. The soil at each site is a moderately heavy loam.

METHOD OF SURVEY.—Each survey

area consisted of a plot of 10,000 square feet and was laid out in 14 rows, 7 feet apart; 14 square-foot diggings, 7 feet apart, were made in each row. This made a total of 196 diggings, spaced equidistant apart in each plot, and represented approximately 2 per cent of each plot area. The diggings were made to a depth of 8 inches, the soil removed and screened, and all the host grubs carefully examined for parasite eggs and larvae. The surveys were made in the latter part of June when practically all the female *Tiphia* had disappeared. Owing to the short time between the disappearance of the *Tiphia* and the emergence of the beetles—approximately 1 week—and the limited amount of labor available, it was impossible to make more extensive surveys.

RATE OF PARASITIZATION IN SURVEY PLOTS.—In table 1 are given the number of parasitized grubs obtained in the 196 diggings made at each survey plot.

Table 1.—Parasitization of Japanese beetle grubs by *Tiphia vernalis* at the Rushland and Philmont survey plots in 1935 and 1936.

	RUSHLAND 1935	RUSHLAND 1936	PHILMONT 1936
Total host population in the 200 diggings	1111	791	1130
Number of parasitized grubs in the 200 diggings	684	373	658
Percentage of parasitization	61.6	47.2	58.2
Average host population per digging	5.7	3.9	5.6

While these surveys show a favorable rate of parasitization near the areas of adult *Tiphia* concentration, it was found that this rate declined as the distance from the feeding area increased, and sample diggings farther out in the fields revealed a much lower percentage of parasitization. The grub population as found in these surveys represents a moderate infestation in the older area of Japanese beetle infestation.

RATE OF SUPERPARASITIZATION IN SURVEY PLOTS.—Apparently the female *Tiphia* is not capable of differentiating between grubs bearing parasite eggs and those not parasitized and will readily oviposit on any host grub with which it comes in contact. After the female stings and temporarily paralyzes the grub, she proceeds to soften and wear down the ventral integument of the derm surface by kneading with her mandibles, and rasping with her roughened pygidium, the area near which the egg is to be placed. This process permits easier perforation of the derm of the grub by the newly hatched parasite larva. Unfortunately this manipulation of the grub by the female invariably destroys any previously deposited eggs as well as the newly hatched larva; but when the larva has reached the third stage, the *Tiphia* shows no interest in the host grub because by this time the latter has become weakened and flabby from the feeding of the parasite.

In view of this general habit and the abundance of females at each survey plot, all grubs were carefully examined for superparasitization. This was easily determined, with the aid of a hand lens, by the egg scars on the grubs or the eggshells still adhering to the host derm. The results of these observations are shown in table 2.

This table, in connection with table 1, shows that 451 grubs, or 40.6 per cent of the total host population obtained at the survey plot at Rushland in 1935, were oviposited upon from 1 to 10 times; and that 165 grubs, or 20.9 per cent of the total host population obtained at the same location in 1936, were oviposited upon from 1 to 13 times. At the Philmont plot survey, 457 grubs, or 40.4 per cent of the total host population, were oviposited upon from 1 to 14 times. At Rushland in 1935, a total of 1806 eggs was deposited on the grubs obtained in the survey plot, of which 1122 were destroyed, giving a potential egg wastage of 62.1 per cent; while in 1936, a total of 780 eggs was deposited on the grubs obtained in the survey plot, of which 407 were destroyed, giving a potential egg wastage of 52.2 per cent. At the Philmont survey plot, 1938 eggs were deposited on the grubs, of which 1,280 were destroyed, giving a potential egg wastage of 66.0 per cent. It is interesting to note the similarity in the percentages of parasitization, the number of grubs bearing egg scars and the total number of eggs destroyed in the surveys made at Rushland in 1935 and at Philmont in 1936, where the total host populations were practically the same at both survey plots.

It is possible that a few of these eggs

and young parasite larvae were rubbed off or crushed by the parasitized grub moving through the soil, but most of this destruction is attributed to the lack of dispersion on the part of the female parasites from the feeding area and an insufficient supply of host grubs to accommodate the concentration of females. Observations in the field have shown that the female *Tiphia*, after feeding, either drops to the ground nearby or flies only a short distance before entering the soil in search of host grubs on which to oviposit.

RELATION BETWEEN SUPERPARASITIZATION AND DISTANCE FROM FEEDING AREA.—In order to determine if there was any relation between superparasitization and distance from the adult feeding area, counts were made of all destroyed eggs every 14 feet from the point of *Tiphia* congregation. The results of these counts are given in table 3.

Table 2.—Superparasitization by *Tiphia vernalis* at the Rushland and Philmont survey plots in 1935 and 1936.

Number of Egg Scars on Each Grub	Number of Parasitized Grubs Bearing Egg Scars	Number of Non-Parasitized Grubs Bearing Egg Scars	Total Grubs Bearing Egg Scars	Total Number of Eggs Destroyed
		Rushland, 1935		
1	179	7	186	186
2	85	4	89	178
3	61	3	64	192
4	42	2	44	176
5	37	3	40	200
6	15	—	15	90
7	9	—	9	63
8	1	—	1	8
9	1	—	1	9
10	2	—	2	20
Total	432	19	451	1,122
		Rushland, 1936		
1	59	12	71	71
2	33	5	38	76
3	15	7	22	66
4	14	1	15	60
5	5	—	5	25
6	5	—	5	30
7	4	—	4	28
8	1	—	1	8
9	1	—	1	9
10	1	—	1	10
11	1	—	1	11
13	1	—	1	13
Total	140	25	165	407
		Philmont, 1936		
1	119	24	143	143
2	114	20	134	268
3	62	7	69	207
4	38	2	40	160
5	18	2	20	100
6	13	—	13	78
7	15	—	15	105
8	7	—	7	56
9	5	1	6	54
10	4	—	4	40
11	5	—	5	55
14	1	—	1	14
Total	401	56	457	1,280

At each survey plot the average number of ovipositions per parasitized grub decreased gradually as the distance from the feeding area was increased, thereby suggesting that within a certain area there is a direct relation between superparasitization and the distance from the feeding point. Sample diggings farther out in the field at each colony site showed no indication of superparasitization.

Table 3.—Relation between superparasitization and distance from the feeding area.

Distance in Feet from Feeding Area	Total Number Parasitized Grubs in 28 Diggings	Total Number Destroyed Eggs on These Grubs	Total Number Eggs Laid on These Grubs	Average Number Eggs Laid per Grub
		Rushland, 1935		
0–14	117	293	410	3.50
14–28	113	235	348	3.08
28–42	107	213	320	2.99
42–56	99	175	274	2.77
56–70	126	108	234	1.86
70–84	85	71	156	1.84
84–96	37	6	43	1.16
		Rushland, 1936		
0–14	60	122	182	3.03
14–28	53	77	130	2.45
28–42	67	81	148	2.21
42–56	53	34	87	1.64
56–70	63	31	94	1.49
70–84	45	9	54	1.20
84–96	32	6	38	1.19
		Philmont, 1936		
0–14	78	210	288	3.69
14–28	70	154	224	3.20
28–42	97	161	258	2.66
42–56	84	167	251	2.99
56–70	97	183	280	2.89
70–84	93	145	238	2.56
84–96	139	148	287	2.06

SUMMARY.—Although the surveys described in this article are limited, and by no means conclusive, they indicate that the feeding habits of *Tiphia vernalis* adults are important factors in the spread and efficiency of this parasite against the Japanese beetle. When the distribution of honeydew is limited or concentrated, the *Tiphia* are attracted from the surrounding area and congregate on the infested trees and shrubs for their food supply. When this occurs, the spread and efficiency of the parasite is lowered through its lack of dispersion, and superparasitization results, especially in those areas where the host population is of insufficient density to accommodate the parasite. Colonies liberated in areas where the adult food supply is entirely absent or where it is very limited rarely become established.

It has been found that Japanese beetles disperse very readily and deposit their eggs over a wide area, but the grubs are usually more abundant near the trees and shrubs on which the adults feed. This condition is favorable for the parasite and tends to increase its efficiency by lessening superparasitization, especially in those areas where the *Tiphia* are attracted to the same trees and shrubs for their food supply.—12-17-37.

FEDERAL quarantine regulations relating to the pink bollworm of cotton were amended, effective January 3, to add to the lightly infested area all of Santa Cruz County, Arizona, and parts of Pima and Pinal Counties in the same state.

THE GYPSY MOTH quarantine of the state of Pennsylvania was revised on February 1 to modify the regulated area in the five infested counties in that state and to designate generally infested and lightly infested areas.

Tartar Emetic as a Field Spray Against the Gladiolus Thrips

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The most commonly used sprays for the control of the gladiolus thrips, *Taeniothrips simplex* Morison, on growing plants are modifications of the Paris green and brown sugar mixture first suggested by Dustan (1931) of the Canadian Department of Agriculture. Dustan's original recommendation was 2 tablespoonfuls of Paris green and 2 pounds of brown sugar in 3 gallons (Imperial) of water, which is equivalent to approximately 4 pounds of Paris green and 66 pounds of brown sugar in 115 U. S. gallons. Richardson & Nelson (1933), using the same quantity of brown sugar but only 2 pounds of Paris green per 100 gallons, found it the most effective of 14 spray mixtures tested during the summer of 1932. Richardson (1934) subsequently found that a 3 per cent molasses solution could be used in place of brown sugar with increased toxicity to the thrips. Tate (1934) suggested a by-product of the corn syrup industry as less expensive than brown sugar.

All these Paris-green combinations, while giving good thrips control, have the same objectionable feature, a tendency to burn the gladiolus foliage, and under certain conditions burning may be severe.

Various Arsenicals Used.—Other arsenicals in combination with brown sugar in the same proportion have been suggested. McKenzie (1935) recommended manganese arsenate, 4 pounds per 100 gallons, for use in California. Magnesium arsenate, 2 pounds per 100 gallons, has also been advocated. In the vicinity of Washington, D. C., both these combinations caused foliage injury, that from the manganese arsenate being only slightly less than that from Paris green in the same planting. The writer (1936) found lead arsenate at the rate of 6 pounds per 100 gallons to be less injurious than any of these combinations, causing only slight burning. Even a small amount of burning is objectionable, however.

Tartar Emetic.—In view of these objections to the arsenicals, many other insecticidal materials have been tested during the last 3 years in an effort to develop a combination highly toxic to the thrips and noninjurious to the gladiolus plants. Of 11 materials tested last spring on forced plants in the greenhouse, one, tartar emetic (antimony and potassium tartrate, U.S.P.), gave control equal to that given by the standard Paris green mixture; furthermore, it did not burn the foliage. Accordingly, a number of tartar emetic combinations have been tested in the field during the past summer, and the results are presented here. The only published account of the use of this material against the gladiolus thrips is that by Richardson (1934), who states that a 1-to-400 dilution with 3 per cent of molasses was very toxic to adult thrips in laboratory tests.

Sprays Tested.—Seven sprays containing tartar emetic and two containing Paris green were used. The quantity of brown sugar generally used in arsenical sprays tends to make the foliage sticky and also makes the spray rather expensive. To determine whether the proportion of this material could be reduced when used with tartar emetic, three dilutions were used with each of two dilutions of the insecticide. In addition, one spray each of tartar emetic and Paris green was made up with a spreader-sticker, ammonium caseinate and rosin residue emulsion, to determine whether such a combination would be as effective as the sweetened mixtures. This spreader-sticker was prepared by L. D. Goodhue as described in a recent publication (Goodhue & Fleming 1936). A standard Paris green and brown sugar mixture was also included in the tests for comparison.

Procedure.—Five thousand corms of each of two varieties of gladiolus, Crimson Glow and Virginia, were planted for these tests. Each variety was planted in 10 rows of 10 plots each, with 50 corms per plot. The distance between rows and also between plots was 6½ feet. Each of the nine sprays, as well as an unsprayed check, was replicated 10 times on each variety. The Latin square method of plot arrangement was used.

A short time before being planted, the corms were infested with thrips, and by

the time the plants were 4 to 6 inches high a large population was present in all the plots. Six weekly spray applications were made, the first on June 24 and the last on July 28, when the first flowers were cut. The sprays were applied with a continuous-pressure knapsack sprayer, which delivered a fog spray. Enough of the material was applied to cover the foliage with fine droplets but not enough to wet the leaves completely, since this causes excessive run-off.

A large number of plants of the variety Crimson Glow were infected with scab, *Bacterium marginatum* McCulloch, which resulted in the death of many plants and a marked reduction in the number of flowers. Hence, the data presented here are based only on the variety Virginia, in which no complicating disease was present.

All flower spikes in all plots were cut at two or three day intervals. The peak of blooming occurred during the week of August 9, or about two weeks after the last spray application. As each spike was cut, it was graded as follows according to thrips injury:

Grade 1.—Flower spikes with no thrips injury, except for occasional spikes with one or two of the open florets that had one or two inconspicuous small flecks, caused by thrips.

Grade 2.—All spikes with florets showing thrips injury, from those having noticeable thrips-fed areas on the petals to those completely blasted.

Richardson & Nelson (1933) showed that there is a direct correlation between the number of thrips present and the degree of injury to the flowers. Hence, the percentage of grade 1 flowers offers a reliable index of the effectiveness of a given spray as compared with an unsprayed check.

PLANT TOLERANCE.—Observations on the effect of the various sprays upon the gladiolus foliage were made periodically as the spraying season advanced, and also the last week in August, or about three weeks after the final spray application. None of the tartar emetic sprays caused any burning, and there was little evidence of thrips feeding except on the plots sprayed with the unsweetened combination, where "silvered" areas were observed. Both Paris green combinations resulted in typical injury; that is, one or two of the lower leaves became partly or entirely brown and the upper leaves had burned spots, especially in thrips-fed areas, which were more extensive on the plants sprayed with the unsweetened mixture. In the check plots there were large thrips-fed areas on most of the plants.

RESULTS.—The data on the total number of spikes cut, the mean percentages of grade 1 and grade 2 spikes, the per cent control and the mean unit weights of the planted and harvested corms are presented in table 1.

The percentage of control was calculated by means of Abbott's formula (1925): $(x-y)100/x$, where x was the mean percentage of grade 2 spikes in the check and y the mean percentage of grade 2 spikes in the treated plot. These data indicate that all the sprays containing brown sugar gave excellent control, but that the two unsweetened sprays were not nearly so effective.

The data on the percentage of grade 1 spikes cut from each of the 100 plots, from which the means in table 1 were obtained, were subjected to an analysis of variance (Fisher 1936). Briefly, it was found that the standard error of the difference between the means of any two treatments was 4.1 per cent, and that a difference of 11.8 per cent was required for significance between any two of these means. This figure was calculated at the significance level of 99 to 1. It is apparent, therefore, that all the sprays caused a very significant increase in the mean percentage of grade 1 spikes as compared with the check, that the seven sprays containing brown sugar gave results significantly better than the two unsweetened combinations and that there is no significant difference between the seven sweetened sprays.

The planted corms were size number 2, that is, $1\frac{1}{4}$ to $1\frac{1}{2}$ inches in diameter. All lots were weighed previous to planting and the mean unit weights are given in table 1. As these data indicate, there was very little variation in the weight of the planted stock. The extremes in average unit weight were, in fact, 14 and 14.8 grams.

Three weeks after being dug, the harvested corms were cleaned and weighed.

Table 1.—Field tests with tartar emetic as compared with Paris green sprays against the gladiolus thrips on gladiolus, variety Virginia, Beltsville, Md., 1937.

Spray Material	Quantity Per 100 Gallons	Number of Spikes	Mean Per Cent of Grade 2 Spikes	Mean Per Cent of Grade 1 Spikes	Per Cent Control	Mean Unit Weight of Corms in Grams	
						Planted	Harvested
Tartar Emetic Brown Sugar	8 lb. 16 lb.	346	7.5	92.5	91.3	14.4	33.1
Tartar Emetic Brown Sugar	8 lb. 32 lb.	378	8.7	91.3	89.9	14.4	33.9
Tartar Emetic Brown Sugar	8 lb. 64 lb.	396	7.3	92.7	91.6	14.5	32.3
Tartar Emetic Brown Sugar	4 lb. 16 lb.	394	8.6	91.4	90.1	14.3	35.6
Tartar Emetic Brown Sugar	4 lb. 32 lb.	394	11.7	88.3	86.5	14.4	33.9
Tartar Emetic Brown Sugar	4 lb. 64 lb.	386	8.8	91.2	89.8	14.5	35.1
Tartar Emetic Ammonium Caseinate and Rosin Residue	8 lb. 1 qt.	403	60.8	39.2	29.9	14.5	31.8
Paris Green Ammonium Caseinate and Rosin Residue	2 lb. 1 qt.	396	31.8	68.2	63.3	14.4	21.8
Paris Green Brown Sugar	2 lb. 64 lb.	400	11.0	89.0	87.3	14.4	26.7
Check (Unsprayed)		390	86.7	13.3		14.4	34.2

The mean unit weights of these corms are also given in table 1. It will be noted that there was a weight increase over the planted corms in all cases. However, the corms from the two Paris green treatments show considerably less increase than the check and tartar emetic plots.

The data on the mean unit weights of the harvested corms were analyzed for variance. It was found that the standard error of the difference between the means of any two treatments was 1.88 grams and that, at the level of 99 to 1, a difference of 5.4 grams is required for significance between any two of these means. On the basis of this figure there is no significant difference between the mean unit corm weights of any of the tartar emetic and brown sugar plots and the check. The results for the two Paris green treatments are not statistically different and both are significantly lower than any of the other treatments, except that there is no difference between the tartar emetic ammonium caseinate and rosin residue emulsion and the Paris green and brown sugar treatments.

From these data it appears that the sprays of tartar emetic and brown sugar did not interfere with normal corm production but that the Paris green combinations had a deleterious effect upon new corm growth, probably due to the foliage burning resulting from their use.

Table 2.—Comparative cost of two sprays used in field tests with gladiolus thrips, Beltsville, Md., 1937.

Materials	Cost per 100 Gallons
Tartar Emetic, 4 lb.	$2.28
Brown Sugar, 16 lb.	.96
Total	$3.24
Paris Green, 2 lb.	$0.90
Brown Sugar, 64 lb.	3.84
Total	$4.74

COMPARISONS OF COST.—As there is no significant difference in effectiveness between the six sprays of tartar emetic and brown sugar, the one containing the least of each ingredient is used in table 2 for comparison of cost with the standard Paris green mixture. The figures are based on open market prices paid for the materials used in these tests.

From the quantity of spray required to cover a definite number of plants in the experimental planting, it was estimated that about 1000 gallons would be required per acre per season. The cost of spray materials per acre per season for the tartar-emetic combination would therefore be $32.40, and for the Paris-green mixture $47.40.

CONCLUSIONS.—Although the data presented here are based on only one season's work, the following conclusions are indicated.

Combinations of tartar emetic and brown sugar are not injurious to gladiolus foliage, result in thrips control equal to that obtained with Paris green and brown sugar and have no deleterious effect upon new corm production; an effective mixture of tartar emertic and brown sugar can be prepared for less cost than a spray of Paris green. With the tartar emetic, the amount of brown sugar can be reduced to one-fourth of that commonly used with arsenicals without affecting the control obtained. Apparently the sprays must be sweetened, however, since the substitution of a spreader-sticker for the brown sugar resulted in poor control with both tartar emetic and Paris green.—12-17-37.

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Insecticidal Tests Against Red Spiders and Thrips on Greenhouse Tomatoes and Cucumbers

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One of the most destructive pests of greenhouse cucumbers and tomatoes is the mite known as the common red spider, *Tetranychus telarius* (L.). Several species of thrips, especially the onion thrips, *Thrips tabaci* Lind., are also very injurious to these crops. Richardson (1935) conducted tests in a commercial greenhouse with a spray consisting of a suspension of 1 pound of powdered derris root in 100 gallons of water (0.0034 per cent of rotenone in the diluted spray) with sulfonated castor oil (1 to 300) added as a spreader. A kill of 98.4 per cent of red spider adults and of 96.4 per cent of nymphs on cucumbers resulted. In the same house, tests with a spray containing lauryl and mixed thiocyanates (about 0.083 per cent of active ingredients) with sulfonated fish oil as a wetting agent gave a high kill (94 to 99 per cent) of red spider nymphs and adults. No injury to the cucumber plants resulted from either spray.

EXPERIMENTAL PROCEDURE.—The experiments described herein were conducted in a greenhouse approximately

29 feet wide by 75 feet long. The usual commercial practices were followed in growing the tomato (variety, Marglobe) and cucumber (variety, White Spine) plants, one-half of the house being planted to each crop. The plants were set out March 24 and 26, 1937, and later trained to stakes and overhead wires. To hasten the development and increase of an infestation, leaves from clover and tomato plants carrying large populations of red spiders were placed upon the experimental plants. By the end of May the infestation was sufficiently large to permit undertaking the spraying tests. Eleven spray mixtures were tested, as indicated in table 1. Analyzed samples of finely ground root were used in making the derris and cubé sprays.

Table 1.—Composition of sprays tested against red spiders and thrips on greenhouse tomatoes and cucumbers.

Spray or Plot No.	Material	Quantity per 100 Gallons	Per Cent of Active Ingredient or Dilution of Spreader
1	Derris	1 lb.	Rotenone, 0.0056
	Alkylphenylbenzenesulfonic acid (40% Solution)	1 pt.	1–800
2	Derris	1 lb.	Rotenone, 0.0056
	Sulfonated castor oil	$2\frac{2}{3}$ pt.	1–300
3	Derris	2 lb.	Rotenone, 0.0112
	Alkylphenylbenzenesulfonic acid (40% Solution)	1 pt.	1–800
4	Check (unsprayed)	—	—
5	Derris	2 lb.	Rotenone, 0.0112
	Sulfonated castor oil	$2\frac{2}{3}$ pt.	1–300
6	Derris	1 lb.	Rotenone, 0.0056
	Pyrethrum extract	2 qt.	Pyrethrins, 0.01
	Alkylphenylbenzenesulfonic acid (40% Solution)	1 pt.	1–800
7	Derris	1 lb.	Rotenone, 0.0056
	Pyrethrum extract	2 qt.	Pyrethrins, 0.01
	Sulfonated castor oil	$2\frac{2}{3}$ pt.	1–300
8	Derris	1 lb.	Rotenone, 0.0056
	Ammonium caseinate and rosin residue emulsion	2 pt.	1–400
9	Cubé	1 lb.	Rotenone, 0.0059
	Alkylphenylbenzenesulfonic acid (40% Solution)	1 pt.	1–800
10	Cubé	1 lb.	Rotenone, 0.0059
	Pyrethrum extract	2 qt.	Pyrethrins 0.01
	Alkylphenylbenzenesulfonic acid (40% Solution)	1 pt.	1–800
11	Check (unsprayed)	—	—
12	Proprietary thiocyanate	$2\frac{2}{3}$ pt.	β-Butoxy-β′-Thiocyanodiethyl Ether, 0.083 (1–300)
13	Proprietary thiocyanate	$1\frac{1}{3}$ pt.	Lauryl Thiocyanate, 0.075 (1–600)
	Sodium oleyl sulfate and synthetic resins	1 pt.	1–800

All these sprays were applied to the tomatoes. One plot of 12 plants was used for each spray mixture, and two plots were left unsprayed as checks. All these combinations except the one containing

derris plus ammonium caseinate with rosin residue and the two thiocyanate sprays were applied to the cucumbers. One plot of 14 plants was used for each spray and one plot was left unsprayed as a check.

The applications were made with a power sprayer set at 300 pounds pressure. Tarpaulins were suspended on both sides of a given plot while it was being sprayed to prevent, as much as possible, the insecticides from drifting to the plants in the adjoining plots. Two series of tests were conducted, each of which is discussed below.

Table 2.—Results of two series of spraying tests against the common red spider on greenhouse tomatoes and cucumbers, Beltsville, Md., 1937.

Spray or Plot No.*	First Series			Second Series		
	No. of Red Spiders Examined	Per Cent Mortality	Average No. of Living Red Spiders Per Leaf	No. of Red Spiders Examined	Per Cent Mortality	Average No. of Living Red Spiders Per Leaf
			Tomatoes			
1	0	0.0	0.0	316	59.2	25.8
2	6	100.0	0.0	131	96.2	1.6
3	24	79.2	1.0	340	70.6	20.0
4	805	5.2	152.6	1,063	6.2	199.4
5	2	100.0	0.0	106	97.2	0.6
6	28	100.0	0.0	496	91.3	8.6
7	182	97.8	0.8	569	85.8	16.2
8	359	48.5	37.0	579	66.1	39.2
9	91	54.9	8.2	478	55.0	43.0
10	491	80.6	19.0	902	86.0	25.2
11	777	2.4	151.6	1,134	8.4	207.8
12	155	92.3	2.4	553	88.1	13.2
			Cucumbers			
1	377	85.4	11.0	1,151	46.4	123.4
2	606	100.0	0.0	62	96.8	0.4
3	628	77.7	28.0	1,320	59.4	107.2
4	1,971	3.5	380.4	821	32.4	111.0
5	537	95.7	4.6	47	95.7	0.4
6	711	67.9	45.6	2,100	54.6	190.8
7	129	88.4	3.0	162	88.3	3.8
9	1,759	65.9	120.0	2,091	20.3	333.4
10	259	48.6	26.6	1,300	28.8	184.0

* For details of materials and concentrations see table 1.

First Series of Tests.—The first series consisted of four applications made at four-day intervals from May 28 to June 9, inclusive. Thus for a period of almost two weeks a residue of comparatively fresh insecticide was kept on the plants. It was thought that by such a procedure the population would not build up so rapidly from individuals that escaped a previous application as when the sprays were applied at longer intervals. In some earlier tests it had been observed that the buildup was rather rapid after an interval of a week or 10 days.

Mortality counts were begun 48 hours after the last application. These were based on an examination of all individuals on a random sample of five leaflets picked from each tomato plot and of five medium sized leaves from each cucumber plot. Only the common red spider occurred on the tomatoes, but on the cucumbers both the red spider and the onion thrips were present. Apparently the lauryl thiocyanate spray (no. 13) was used at too high a concentration, since after two applications the tomato plants were so severely injured that its use was discontinued. Therefore, no mortality counts were made from this plot. The data from all other plots are presented in table 2.

Second Series of Tests.—In the second series the plants in the tomato plots were sprayed four times at weekly intervals, on June 15 and 22 and July 6 and 13, the June 29 application being omitted to permit sufficient increase in population to give the sprays a thorough test. Examinations were made on July 15 and 16, being begun 48 hours after the last

application, and counts were made in the same manner as for the first series. In the cucumber plots the plants received eight spray applications, on June 15 and 22, July 2, 6, 13, 20 and 27, and August 3.

The dates of application were governed by the appearance of the plants and by the severity of the infestation. The purpose of extending the spraying schedule on the cucumber plants was to determine how much longer they could be kept in a good growing condition if the red spiders were held in control by a more or less regular spraying procedure. Mortality counts, however, were made July 22, or 48 hours after the sixth spray application, in the same manner as described for the first series. The data are incorporated in table 2.

EFFECT ON THE RED SPIDER.—In the first series the red spider population in the tomato plots was somewhat low and unevenly distributed; so no conclusions can be drawn from the tests. When compared, however, with the untreated plots, or checks, all the plots except nos. 3, 8, 9 and 10 appeared to give good results. In this connection it was noted that each check plot (nos. 4 and 11) carried an infestation averaging about 152 living individuals per leaf.

In the second series of tests on tomatoes, where better counts were obtained, the following results are indicated:

1.—With the same amount of derris the spreader sulfonated castor oil resulted in a better kill than alkylphenylbenzenesulfonic acid, or ammonium caseinate with rosin residue emulsion (compare sprays nos. 1 and 8 with spray no. 2, and no. 3 with no. 5.) The addition of pyrethrum extract to the derris and alkylphenylbenzenesulfonic acid mixture appeared to increase its acaricidal effect (compare no. 1 with no. 6). This effect was not evident on the cucumbers, as noted below.

2.—Where the sulfonated castor oil was used as a spreader, doubling the amount of derris did not appear to increase the kill (compare no. 5 and no. 2), the mortality being very high with both combinations. Where alkylphenylbenzenesulfonic acid was used as a spreader and the percentage of kill was rather low (no. 1), doubling the amount of derris (no. 3) appeared to increase the toxicity somewhat. This increase, however, was not so much as might be expected because of the increased content of rotenone and other extractives in this combination.

3.—Cubé plus alkylphenylbenzenesulfonic acid (no. 9) did not appear effective, but when pyrethrum extract was added (no. 10) the toxicity was greater.

4.—The proprietary thiocyanate spray (no. 12) was also very effective.

In the tests on cucumbers large populations of spiders were present in both series. The results in general followed the same trend as those of the second series on tomatoes, with the following exceptions:

1.—The addition of pyrethrum to the derris plus alkylphenylbenzenesulfonic acid mixture did not increase its effectiveness (compare nos. 1 and 3 with no. 6).

2.—In the first series where the quantity of derris was doubled and alkylphenylbenzenesulfonic acid used as a spreader, the kill was not increased but in fact appeared to have been decreased (compare no. 3 with no. 1). In view of the results with these two combinations on tomatoes, as discussed above, and in the second series on cucumbers, this reduction cannot be explained at this time.

3.—Neither of the cubé combinations was very effective.

In general, the sprays that proved effective in the first series continued to be effective in the second series, as is indicated by the subsequent low build-up of the red spider population. The build-up was much greater in the plots that received the less effective sprays.

The greater effectiveness of the derris sprays as compared with the cubé sprays of the same rotenone content is probably due to the low carbon tetrachloride extractives in the cubé sample tested. This may be explained by calculating the toxic values according to the method of Jones & Smith (1936). The cubé powder, with a rotenone content of 4.9 per cent and 12.3 per cent total extractives, had a toxic value of 7.9 per cent, whereas the derris powder, with a 4.7 per cent rotenone content and 18.6 per cent of total extractives, had a toxic value of 11.6 per cent.

EFFECT ON THE ONION THRIPS.—Since the numbers of the onion thrips present on the cucumbers were small, no detailed tabulation of the observations will be presented. The mortality counts indicate that the derris sprays containing sulfonated castor oil were generally more ef-

fective than those containing alkylphenylbenzenesulfonic acid. When pyrethrum extract was added to the latter spray, however, the mortality was equal to that obtained with the castor oil sprays, which ranged from 95.3 to 100 per cent. The cubé sprays, as was expected, gave lower mortalities than the derris sprays.

In similar tests conducted in 1936 on cucumber with some of the same spray combinations, it was found that the addition of pyrethrum increased the effectiveness of both derris and cubé sprays against the onion thrips, especially the immediate effectiveness against the adults and nymphs. As in this season's tests, the cubé sprays were not so effective as those containing derris, even though the rotenone content (0.0056 per cent) was the same. This was probably due to the difference in the amount of total extractives, as previously explained. One of the same thiocyanate sprays as was used in this year's tests on tomato, diluted 1 to 300 (no. 12), was more effective without sulfonated castor oil than when diluted 1 to 600 with this spreader added. A lauryl thiocyanate, 1 to 500, plus sulfonated castor oil, 1 to 400, gave a higher mortality than did the proprietary thiocyanate (no. 12) at the same dilution.

In the tests of 1936 all the sprays caused a marked reduction in the number of living thrips per leaf. A reduction in the number of living newly hatched nymphs indicated a possible residual action. The lauryl thiocyanate plus sulfonated castor oil caused a rather severe spotting of the cucumber foliage. None of the derris or cubé sprays caused any injury, and in this respect the results agree with those obtained this year. In all the sprayed plots little or no mildew appeared, whereas in the check plot it was constantly present. This may indicate some fungicidal action from the sprays under the conditions of these experiments.

PLANT TOLERANCE.—As previously indicated, two applications of a lauryl thiocyanate spray, 1 to 600, severely injured tomato. None of the other sprays caused any permanent injury. In those sprays containing sulfonated castor oil, however, a noticeable spotting of the green fruit on the tomato vines occurred. Syringing with water within 48 hours after spraying lessened such spotting. The spraying had a beneficial effect, because in the check plants a progressive dying of the foliage from the base of the plant to the top continued throughout the tests. The lower leaves died early in the experiment, and by July 19 this killing extended half way up the plants. When the crop was removed, about the middle of August, the plants were almost dead, and such fruit as remained was badly marred. This condition was absent in the sprayed plots, except for the natural dying of the leaves at maturity.

On cucumber the same condition as occurred on tomato was observed. None of the sprays caused any permanent injury, and the same beneficial effect from the spraying was noted. The color and vigor of the plants appear to be correlated with the average number of living red spiders remaining on the foliage. Spray plots nos. 2, 5 and 7, for example, retained the healthiest appearance throughout the tests, as indicated by low populations of red spiders in contrast to the high populations in the checks. Since all the sprays used on these plots contained sulfonated castor oil as a spreader, it is believed that this material increased the effectiveness of these sprays.

SUMMARY.—Mortality counts of common red spiders and onion thrips on greenhouse grown tomato and cucumber plants were taken after various spray applications in two series of tests. The results of the first series indicate that a derris spray having a rotenone content of 0.0056 per cent is as effective as one with a 0.0112 per cent rotenone content when sulfonated castor oil is used as a spreader; that the derris sprays used in these tests are superior to cubé sprays of the same rotenone content, the difference being explainable on the basis of the total extractives; that the addition of pyrethrum extract aids in killing thrips but does not improve the spray's effectiveness against the red spider; that with sprays of the same rotenone content with sulfonated castor oil as a spreader, the kill is better than with either alkylphenylbenzenesulfonic acid or ammonium caseinate with rosin residue; and that proprietary thiocyanate spray (no. 12) is as effective as the derris spray plus sulfonated castor oil.

The red spider population on those plots in which poor control was obtained

during the first series showed a continued build-up in numbers at the end of the second series, whereas in those plots showing good control in the first series the increase in numbers was negligible in the second series.

None of the derris or cubé sprays plus the spreader or the proprietary thiocyanate caused any permanent injury to either tomato or cucumber. The lauryl thiocyanate spray with a sodium oleyl sulfate plus synthetic resin spreader caused severe injury to both the foliage and fruit of tomato.

On the whole a beneficial effect from the spraying was clearly shown by the following results:

1.—On the sprayed plants the foliage remained greener much longer than on the check plants, and the sprayed plants continued to bear fruit much longer than the check plants.

2.—The average number of living red spiders per leaf in the effectively sprayed plots for the two series was very low in contrast to the checks, and the plants continued to make a healthy growth.—12-17-37.

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The Use of Nicotine in Codling Moth Control with Special Reference to Its Effectiveness in Killing Moths

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Although Weldon (1909) first demonstrated that the percentage of wormy apples was reduced by nicotine sprays, his results led him to believe that nicotine preparations were of little value in a spray program against the codling moth. The following year Gillette (1910) reported 73 to 77 per cent clean fruit from the use of nicotine sulfate and nicotine extract respectively, whereas the unsprayed check fruit was 58.9 per cent free from injury.

Several years later De Sellem (1915) used nicotine sulfate for codling moth control at Yakima, Washington. He stated that control might be due to the repellent action of nicotine against the moth or that the larvae refused to eat. Lovett (1918) found nicotine sulfate to be an effective ovicide against eggs of the codling moth and Howard (1918) reported that work in the Bureau of Entomology indicated that nicotine alone was not sufficiently effective as an ovicide to give satisfactory control. McIndoo, Simanton, Plank & Fiske (1921) obtained a high percentage of hatch among codling moth eggs that had been sprayed with nicotine sulfate. At the same time, the authors reported 77.7 and 72.2 per cent kill of young larvae that were placed on pears which had been sprayed with nicotine sulfate one and two days previously.

NICOTINE AS AN OVICIDE.—Thus the experimental data based on investigations made from 1909 to 1921 indicated that nicotine had some ovicidal effect on codling moth eggs and that it also acted as a larvicide.

The apparent disagreement in results of the early work with nicotine sulfate as an ovicide may be accounted for by differences in the age of the eggs used in the tests. Experiments made (Hough & Jefferson 1936) with nicotine sulfate as an ovicide for codling moth eggs of various but known ages showed that a very high percentage of kill was obtained against eggs due to hatch within a few hours, while eggs recently deposited were much less affected by the nicotine.

The relation between the age of codling moth eggs at the time of spraying and the percentage of hatch following the application of certain nicotine compounds is shown in fig. 1. These data are based on tests made in 1934 and 1937 which involved spraying 12,390 eggs of known ages. The eggs were deposited on pear

leaves. It will be observed that the percentage of eggs which hatched decreased with the decrease in the interval between the time of spraying and the time of hatching. Newly deposited eggs were scarcely affected by sprays of nicotine bentonite (*Black Leaf 155* made according to the 1934 formula containing 8 per cent nicotine and used at the rate of 5 pounds per 100 gallons) or nicotine oleate at 1½ pints fixed with 4 pounds of a bentonite fixative per 100 gallons. Nicotine sulfate (*Black Leaf 40*) was used at the rate of 1 pint per 100 gallons. It is evident that nicotine sulfate was not an effective ovicide for codling moth eggs which were more than one day from their normal hatching time when sprayed.

EFFECT ON THE MOTHS.—Because the control of codling moth is measured by the percentage of clean fruit resulting from the use of a given material, usually our attention is focused on the effectiveness of a treatment as a larvicide or ovicide. Consequently, we were somewhat surprised when we observed (Hough 1934) that moths were killed by volatile nicotine from some of our orchard sprays containing nicotine compounds. Smith, Myer & Persing (1934) found that nicotine vapor was highly toxic to codling moths. Heat was employed in vaporizing the nicotine. To insure proper concentration of the toxic material in the atmosphere surrounding the tree, a portable fumatorium or tent was placed over each tree prior to the introduction of the vapor. These authors found that "1 cc. of *Black Leaf 50* when vaporized was more effective in killing the moths than was 30 cc. of liquid HCN." In fumigating an apple tree of approximately 4500 cubic feet in volume they used 6 cc. of *Black Leaf 50* and killed all moths.

DESCRIPTION OF MOTH KILLING EXPERIMENTS.—In order to obtain an estimate of the efficacy of nicotine sprays in killing the moths under orchard conditions, we began a series of experiments in 1935 in which sheets were placed under Grimes Golden apple trees of similar size and shape and averaging about 13 feet in height. A known number of moths was liberated on the trees prior to spraying. Early in these experiments we discovered that most of the sheets were too small to catch all of the moths as they fell or drifted out of the trees. This source of error was partially corrected by the use of larger sheets in the experiments conducted in 1936 and 1937, and for this reason it was possible to combine the results of comparable tests made during these years. Another source of error was that some moths were blown from the sheets in some of the tests. It was found, also, that some of the moths adhered to the foliage or limbs after becoming wet with the spray and, although dead, they did not fall. Some of these fell after the tree became dry and the limbs were jarred. Such sources of error contributed to variations in our results, but in each instance the number of dead moths found was a conservative estimate of the minimum kill obtained.

Short rods (4 to 6 feet long) with multiple nozzles which delivered a finely divided spray under 325 pounds pressure were used in applying the sprays. In 1937 one man standing on the ground sprayed each tree as he walked completely around it. In previous years two men applied the sprays, one from the top of the tank and the other when standing on the ground.

Each series of tests recorded in table 1 is the summary of three or more replicates made each season. The highest percentage killed as well as the lowest is shown for each series. The wide range in the kill obtained appeared to be due to the sources of error already mentioned rather than to variations in the temperature. In fact, we obtained some of the highest percentages of kill while the temperature was at or near 70 degrees F. In two of the three tests, made while the temperature was 66 degrees F., the percentage of dead moths recorded was greater than when the same tests were made at considerably higher temperatures. In short, we could find no relation between the percentage of dead moths found and the temperature at the time of spraying. On the other hand, strong winds reduced the number of moths found and on several occasions nearly all of the moths were blown from the sheets, which completely nullified results of the test.

RESULTS OF MOTHKILLING EXPERIMENTS.—A study of the results recorded in table 1 shows that all of the nicotine sprays were about equally effective in killing moths, except those of fixed nicotine (series 6 and 7). *Black Leaf 40* at the

rate of one-half pint (series 10) was not quite as effective as when used at three-fourths pint or 1 pint per 100 gallons. In series 8, the amount of bentonite fixative was reduced so that only half of the nicotine was combined with the bentonite. It will be seen that the kill obtained compared favorably with results from sprays containing either *Black Leaf 40* or *Black Leaf 50*.

In the tests of 1937 the addition of a small amount of hydrated lime to sprays the other applications was 72.5 per cent.

Even though we assume that the total kill might not exceed the percentages indicated in our tests, the effectiveness of nicotine in destroying moths appears to be sufficient to warrant the suggestion that nicotine may be used in orchard sprays to reduce the build-up of the moth population in heavily infested orchards. During the past 10 years quite a number of investigators have reported (McIndoo, Roark & Busbey 1936) that nicotine sul-

Table 1.—Results of experiments on the effectiveness of various nicotine sprays in killing codling moths released on apple trees.

Year	Series	Materials and Amount Per 100 Gallons	Number of Moths		Per Cent Killed		
			Released	Killed	Average	Highest	Lowest
1935	1	Nicotine Bentonite, 6 lbs. (8% nicotine); lime, 6 lbs.	190	136	71.5	91.6	57.1
1935	2	Nicotine Bentonite, 4 lbs.; lime, 2 lbs.	190	131	68.9	81.6	58.3
1935	3	*Black Leaf 40*, 1 pt.; lime, 2 lbs.	190	111	58.4	80.0	42.8
1935	4	*Black Leaf 40*, 1 pt.; lime, 6–8 lbs.	190	130	68.4	71.4	63.3
1935	5	*Black Leaf 50*, 1 pt.	210	165	78.5	96.6	50.0
1936	6	Nicotine bentonite, 8 lbs. (5% nicotine).	210	68	32.3	34.2	28.5
1937	7	Nicotine oleate, 1½ pts.; *Fixator-A*, 4 lbs.	260	112	43.0	63.0	23.0
1937	8	Nicotine oleate, 1½ pts.; *Fixator-A*, 2 lbs.	293	207	70.7	87.6	56.9
1936	9	*Black Leaf 50*, 1 pt.	220	177	80.4	98.7	64.2
1936	10	*Black Leaf 40*, ½ pt.	210	139	66.1	77.1	58.5
1936 1937	11	*Black Leaf 40*, 1 pt.*	535	415	77.5	94.2	63.0
1936 1937	12	*Black Leaf 40*, 1 pt.; lime, 1 lb.*	578	437	75.6	94.6	47.0
1936 1937	13	*Black Leaf 40*, 1 pt.; lime, 2 lbs.*	645	503	77.9	90.0	57.3
1936	14	*Black Leaf 40*, 1 pt.; lime, 3 lbs.	270	191	70.7	87.1	48.5
1936 1937	15	*Black Leaf 40*, 1 pt.; *Orthol-K* oil, 1 gal.*	535	380	71.0	91.4	47.6
1936	16	*Black Leaf 40*, 1 pt.; *Orthol-K* oil, 1 gal.; lime, 1 lb.	210	167	79.5	97.1	67.1
1937	17	*Black Leaf 40*, ¾ pt.; *Orthol-K* oil, ¾ gal.*	260	192	73.8	84.6	67.6

* Also lead arsenate, 3 lbs. per 100 gallons, in the tests of 1937

containing *Black Leaf 40* appeared slightly to increase the effectiveness of the treatment, but in 1936 there was no advantage resulting from similar tests. The addition of lime to the oil and nicotine combination (series 16) appeared to make this combination but little more effective than when used without lime (series 15). In combination with the summer oil emulsion, *Black Leaf 40* at 1 pint and at three-fourths pint were equally effective (series 15 and 17). There was no evidence to indicate that lead arsenate altered the effectiveness of any of the sprays in which it was used. Exclusive of the two fixed nicotine sprays (series 6 and 7) the average kill for all of

fate with summer oil has given a control of codling moth comparable to that obtained with lead arsenate. From the data given in table 1 it appears that part of the effectiveness of the oil and nicotine combination is due to destruction of moths by the nicotine.

ORCHARD EXPERIMENTS WITH MOTHS, EGGS, AND LARVAE.—For the past three seasons nicotine has been employed in codling moth sprays chiefly to destroy the moths. The nicotine was used with lead arsenate and summer oil in an attempt to make a triple-acting spray against this insect; that is, a spray to kill the moths, eggs and larvae. The applications were limited to the period of

activity of the first brood in May and June. No attempt was made to control the second brood in July and August. From six to eight acres were usually sprayed in each orchard. The schedules used and the results obtained in 1935 and 1936 have been published (Hough 1936, 1937). In 1937 a schedule (designated as A) of lead arsenate, oil and nicotine similar to the schedules of previous seasons was used in part of the block sprayed in each orchard. The orchards are designated, table 2, by the leading variety, which was also the variety used in the tests. The remainder of the block received no lead arsenate after the first cover (schedule B) but, instead, a part of the nicotine was combined with bentonite to serve as the larvicide. Lead arsenate, 3 pounds per 100 gallons, was used in both orchards for the calyx (May 12) and first cover (May 27–28) sprays. One pint of *Black Leaf 40* was added in the first cover. Beginning with the second cover the following materials were used in schedule A in both orchards: lead arsenate, 3 pounds; *Orthol-K* oil emulsion, 3 quarts; and *Black Leaf 40*, 1 pint in the second (June 9) and third (June 17–18) covers. A fourth cover (June 28) consisted of the same ingredients, except that the lead arsenate was omitted. Materials used in schedule B in the York orchard consisted of $1\frac{1}{2}$ pints of *Black Leaf 40*, 2 pounds of bentonite and 3 quarts of *Orthol-K* oil emulsion in the second, third and fourth cover sprays. Schedule B in the Baldwin orchard consisted of 1 pint of nicotine oleate, $2\frac{1}{4}$ pounds of a bentonite fixative, seven-eighths pint of *Black Leaf 40* and 3 quarts of *Orthol-K* oil emulsion in the second, third and fourth covers, except that the oil emulsion was increased to 4 quarts in the fourth cover because a fungicide (*Coposil*, $1\frac{1}{2}$ lbs.) was added.

Two men applied the sprays. One stood on the ground and used a four nozzle rod while the other occupied a tall tower and used a six nozzle rod. It was essential to spray thoroughly the top part of the trees as well as the lower part in order to reduce the moth population. The results, which include the examination of the drops from early July to picking time, are summarized in table 2. Each set of percentages (wormy and total injuries) is based on the examination of not less than 7217 nor more than 14,258 apples. To obtain the percentage of clean fruit it is necessary only to subtract the per cent of total injuries from 100. The control obtained in the remainder of each orchard is given for comparison.

Table 2.—Results of the examination of the fruit from apple trees which had received sprays intended to destroy the spring brood of codling moth adults, the first brood of eggs and larvae in May and June, 1937, compared to the results obtained from the regular spray schedule used in the remainder of the orchard.

Orchard	Schedule Designation, Insecticides Used Beginning With the Second Cover Spray and Date of Last Spray	Per Cent Codling Moth Injury		Lead Residue
		Wormy	Total	gr./lb.
York	(A) Lead arsenate,* oil and nicotine, June 28	.7	4.7	.092
York	(B) Oil and nicotine, June 28	5.9	13.1	.017
York	Check, not sprayed	54.2	58.0	
York	Remainder of orchard, lead arsenate, 4 covers, July 25	7.5	19.4	.100
Baldwin	(A) Lead arsenate,* oil and nicotine, June 29	1.2	17.6	.095
Baldwin	Same as A but in middle of plot	.3	9.2	.095
Baldwin	(B) Oil and nicotine, June 29	11.2	39.6	.030
Baldwin	Check, not sprayed after May 19	93.1	95.2	.024
Baldwin	Remainder of orchard, lead arsenate, 4 covers, July 23	17.9	56.2	.121

* Lead arsenate omitted in fourth cover, which was applied on June 28 in York orchard and June 29 in Baldwin orchard.

As in previous seasons, the lead, oil and nicotine combination (schedule A) gave satisfactory control. Schedule B in the York orchard also gave satisfactory control, in that 86.9 per cent of the fruit was free from visible injury. In the Baldwin orchard, where the infestation was very severe, schedule B did not give satisfactory control, except on the Wealthy variety which was interplanted with the Baldwin trees. Examination of the Wealthy apples sprayed according to

schedule B showed 91.9 per cent clean fruit (7.2 per cent wormy and .9 per cent with stings) as compared to 97.4 per cent clean fruit (2.4 per cent wormy and .2 per cent with stings) for schedule A. The difference in control obtained on Wealthy and Baldwin apples interplanted in the same spray blocks is accounted for by a difference in varietal susceptibility to

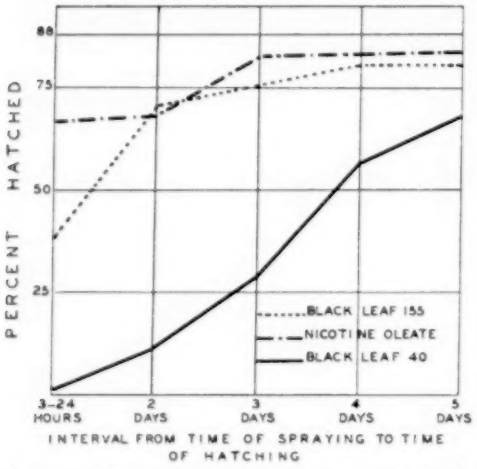

FIG. 1.—Effect of nicotine sprays on codling moth eggs of various ages. The average hatch of 12,129 unsprayed eggs was 88.4 per cent.

codling moth injury and also to the fact that the Wealthy apples were picked from August 20 to 25, whereas the Baldwins were harvested one month later.

Two difficulties arise from the use of schedule A. In the first place, the cost of the ingredients is high, and, in the second place, the residue of lead arsenate, although not especially large in amount, is exceedingly difficult to remove by our present acid washing methods. In fact, we have found a tandem or double wash with warm solutions (first a sodium silicate bath followed by a hydrochloric acid bath) necessary for consistent removal. Ordinarily, the lead residue following the use of schedule B would not exceed the present lead tolerance of .018 grain per pound. But on the Baldwin apples the lead residue was .03 grain per pound because the so-called calyx spray was divided in two applications. The first was made on May 12 and the second on May 19 when the apples were as large as or larger than marbles.

SUMMARY.—Nicotine sulfate was an effective ovicide against codling moth eggs which were due to hatch within a few hours to not more than one day after they were sprayed. Its effectiveness decreased rapidly in proportion to the freshness of the eggs. Fixed nicotine compounds were not effective ovicides for codling moth eggs of any age, although, as in the case of nicotine sulfate, the ovicidal effect varied directly with the age of the eggs at the time of spraying.

Tests of the past three seasons show that orchard sprays containing free nicotine or nicotine sulfate can be employed to kill codling moths. The average kill as determined by the number of dead moths found on sheets that had been placed under apple trees on which moths were released was 72.5 per cent.

Nicotine in combination with summer oil and lead arsenate has been used effectively for three seasons in codling moth sprays designed to eradicate the first brood in May and June. No applications were made against the later broods.

According to the results of 1937, the omission of lead arsenate after the first cover spray and the substitution of fixed nicotine as the larvicide in applications confined to the period of activity of the first brood moths gave satisfactory control in a moderately infested orchard, but, on the Baldwin variety in a heavily infested orchard, control was not satisfactory.—12-17-37.

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Codling Moth Parasitism Under Different Spray Treatments*

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Data and observations have been accumulating at the New Jersey station and elsewhere which show that spraying with lead arsenate on applies to control codling moth has a deleterious effect on several of the codling moth parasites. Driggers & Pepper (1936) showed that codling moth egg parasitism by *Trichogramma sp.* was greatly reduced in orchards sprayed with lead arsenate and oil as compared to unsprayed orchards. They, as well as Cox & Daniel (1935) of the New York station, observed that parasitism of codling moth by *Ascogaster carpocapsae* Viereck also was greatly reduced in orchards sprayed with lead arsenate as compared to unsprayed orchards. Cox & Daniel showed further that the reduction of parasitism was caused by the poisoning of the adult parasites by the lead arsenate.

The development of non-arsenical sprays, such as fixed nicotine, to replace lead arsenate as a control for codling moth naturally raises the question as to whether these sprays interfere with the activities of the various beneficial parasites and predators and, if so, to what extent compared to lead arsenate. Some data along this line have been published by Driggers & Pepper (1936) who showed that apple leafhoppers were less numerous and more heavily parasitized in a section of orchard sprayed with lead arsenate and oil for the first brood, followed by nicotine tannate on the second brood, than in a section where both broods received lead arsenate and oil sprays.

THE EXPERIMENTAL PLOT.—This past season an opportunity was afforded to obtain additional data on codling moth larval parasitism in a series of fixed nicotine plots located in the center of an orchard at Glassboro which was heavily infested with codling moths. This series of plots covering an area 10 by 25 trees had been sprayed with various fixed nicotine formulae the past three seasons except that one-sixth of this group of 250 trees was sprayed with lead arsenate or lead arsenate and oil. Previous to 1935 the whole orchard had been sprayed with lead arsenate for a number of years, and during the past three years the trees surrounding the block of 250 used for experimental plots were sprayed with lead arsenate and oil.

EXPERIMENTAL METHODS.—One of the methods used during the past three years to determine the effectiveness of the various treatments was to scrape and band with burlap three trees in each plot. From these bands, codling moth larvae were collected weekly from the middle of June to harvest time in October.

Cox (1932) has shown that mature codling moth larvae parasitized by *A. carpocapsae* are only one-fourth to one-third the size of unparasitized larvae. Also, the bodies of these small parasitized larvae are generally white, whereas the unparasitized larvae are pinkish-white. These differences are so marked that if any considerable number of parasitized larvae appear under the bands examined weekly they are readily noticed. The first year (1935) the plots were run, larvae parasitized by *Ascogaster* were absent, or they were present in such small numbers that

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they were not noticed. Toward the end of the 1936 spray season, enough of these larvae began appearing under the bands to occasion notice, but no record of them was kept. The first collection of larvae, the last week in June, 1937, showed an appreciable number parasitized in the group of plots as a whole; therefore records were kept for the remainder of the season to see if any variations occurred between plot treatments.

RESULTS OF OBSERVATIONS.—Table 1 sets forth the total larvae of the first and second broods collected from three groups of plots and the percentages of parasitism by *A. carpocapsae*. Parasitism of the first brood was the same in the group of eight fixed nicotine plots and in the group of four fixed nicotine plus oil plots, namely, 8.2 per cent. The two lead arsenate plots (one with lime and the other with lime plus summer oil at peak of egg deposition) averaged slightly higher with 9.9 per cent parasitism. Second brood larvae parasitism increased over first brood parasitism three times (24.9 per cent) on the fixed nicotine plus oil plots and four times (33.4 per cent) on the fixed nicotine plots without oil. Parasitism on the two lead arsenate plots increased during the second brood period from 9.9 per cent to 14.8 per cent, a much smaller increase than that recorded on the fixed nicotine plots.

Table 1.—Codling moth larval parasitism on two lead arsenate sprayed plots, four fixed nicotine plus oil sprayed plots and eight fixed nicotine plots in a Glassboro orchard heavily infested with codling moths.

TREATMENT	FIRST BROOD		SECOND BROOD	
	Total Larvae	Per Cent Parasitized	Total Larvae	Per Cent Parasitized
Lead Arsenate	291	9.9	352	14.8
Fixed Nicotine Plus Oil	1184	8.2	1610	24.9
Fixed Nicotine Alone	2209	8.2	2301	33.4

END OF SEASON CHECK.—It was decided to check the results obtained in table 1 by making a survey of larval parasitism at the end of the season in each plot and in the sections of the orchard sprayed by the grower on either side of the group of experimental plots. In making the survey, 100 larvae were collected from limbs above the crotch on several trees in each plot. The collections were made in October after all the fruit had been harvested and all cocoon formation was completed.

The four samples of 100 larvae each taken from the lead arsenate plus lime plot, the lead arsenate plus oil plot and the grower sprayed sections of the orchard showed 6, 8, 2 and 5 per cent parasitism, average: 5.2 per cent. The four fixed nicotine plus oil plots showed 30, 27, 17 and 34 per cent parasitism; average, 27.0 per cent. The eight fixed nicotine plots showed 60, 30, 28, 28, 35, 29, 37 and 29 per cent parasitism; average, 34.5 per cent. The results of this survey showed a marked difference between the larval parasitism on the lead arsenate sprayed trees and the fixed nicotine sprayed trees. There was also a larger percentage of parasitism on the fixed nicotine without oil plots than on the fixed nicotine plus oil plots, which was in line with the figures on second brood parasitism for these two sets of plots in table 1. For some reason not clear, the parasitism on the lead arsenate plots at the time the survey was made in October was lower than the parasitism on the two lead arsenate plots recorded from the weekly second brood collections.

CHECK ON SECOND PLOT.—The percentage of larval parasitism by *Ascogaster* recorded in this orchard may have been influenced by the heavy codling moth population, which was allowed to build up in 1936 and 1937. It is possible that, in orchards of light or medium codling moth populations, such differences in parasitism between different spray treatments would not be so evident. Fortunately, a series of plots was available in an orchard of medium codling moth infestation at Moorestown where it was possible to secure some data on this question. The series of plots in the Moorestown orchard included one fixed nicotine plot 4 by 9 trees, surrounded on four sides by plots sprayed with lead arsenate plus oil. One hundred codling moth larvae were collected from under the bark in this nicotine plot in October and a similar number of larvae were collected from the lead arsenate plus oil plots surrounding it. No parasitized larvae were found in either the nicotine plot or the lead arsenate plus oil plots. Of course, the area

covered by the one fixed nicotine plot was small compared to the total area surrounding it and sprayed with lead arsenate plus oil. This much larger area has been sprayed year after year with lead arsenate plus oil and this may have reduced *Ascogaster* to such a low point that several years of spraying on larger plots will be necessary before any significant difference in parasitism between the two treatments will become apparent.—12-17-37.

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Further Studies with Lead Arsenate Substitutes for Codling Moth Control*

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The removal of spray residue from apples continues to be an important problem in New York state, especially among growers of tender varieties such as McIntosh, Duchess and Spy. Spray deposits that require even the lightest cleaning operation are objectionable for the reason that the extra handling results in additional bruising of the fruit. A satisfactory summer spray program for use on tender varieties should therefore not only eliminate excessive deposits of lead, arsenic and fluorine, but in addition should leave the fruit free from objectionable amounts of visible residue at picking time.

MATERIALS AND METHODS.—Over a period of several years, nicotine sprays have consistently given most promise as substitutes for lead arsenate in codling moth control under New York conditions. This paper gives the results of orchard experiments conducted during the past season with several nicotine mixtures.

Black Leaf 155 is a proprietary mixture of bentonite and 5 per cent nicotine. It is similar to the *Black Leaf 155-Z* produced in 1936. Eight pounds were used in 100 gallons of water or one-half this amount (4 pounds) when combined with summer oil.

Modified Black Leaf 155 is a modification of *Black Leaf 155* containing soybean oil and Kraya gum. This formula contains 8 per cent nicotine and was used at the rate of 5 pounds in 100 gallons.

Tank mixed nicotine bentonite was made by mixing 4 pounds of a bentonite fixator (Fixator A) and 1½ pints of a nicotine oleate solution (NOL 30), containing 30 per cent nicotine, in 100 gallons of water. When combined with summer oil, 2 pounds of the fixator, three-fourths pint of nicotine oleate solution and 2 quarts of oil were used in 100 gallons of water.

Oil plus nicotine is a tank mixture of 1 pint nicotine sulfate (40 per cent nicotine) with 2 or 3 quarts of summer oil in 100 gallons of water.

RESULTS OF THE EXPERIMENTS.—The tests were made in four mature orchards at different locations in the western New York fruit belt. The varieties were Rhode Island Greening and McIntosh and represented both heavy and light infestations of the codling moth. Thorough treatments were made in which the inside and outside of the trees were sprayed at approximately two-week intervals (unless otherwise noted) during the periods of larval entrance. Table 1 gives the efficiencies of *Black Leaf 155*, nicotine bentonite, oil plus nicotine, lead arsenate and zinc arsenate.

The *Black Leaf 155* (plats 1 to 3) and the nicotine bentonite mixture (plats 13 to 16) appeared about equally effective against the codling moth and when applied at ten-day intervals the efficiencies

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Table 1.—Codling moth control with nicotine sprays, 1937.

Plat No.	Degree of Infestation‡	Variety	Treatment*	Stings on 100 Apples	Per Cent† Efficiency
1	L	Greening	4-*B.L. 155*	3.1	87.9
2	H	Greening	5-*B.L. 155*	3.1	88.8
3	H	Greening	6-*B.L. 155* (10-day intervals)	1.1	93.9
4	H	Greening	1-LA; 2-*B.L. 155*+oil; 2-*B.L. 155*	1.2	98.2
5	H	McIntosh	1-LA; 2-*B.L. 155*+oil; 3-*B.L. 155*	4.6	90.9
6	H	McIntosh	1-LA; 3-*B.L. 155*+oil; 2-*B.L. 155*	5.3	94.9
7	H	McIntosh	1-LA; 3-*B.L. 155;* 2-oil+nicotine	11.1	91.5
8	L	Greening	1-LA; 1-Phenothiazine; 2-*B.L. 155*	4.1	77.5
9	L	Greening	1-LA; 1-ZA; 2-*B.L. 155*	5.7	80.2
10	L	McIntosh	2-ZA; 2-*B.L. 155*	6.0	97.3
11	L	McIntosh	2-ZA; 2-*B.L. 155*+oil	7.9	94.6
12	H	Greening	5-Modified *B.L. 155*	5.8	85.9
13	H	McIntosh	6-NOL 30+Fix. A	7.9	88.4
14	L	Greening	4-NOL 30+Fix. A	3.5	89.0
15	H	Greening	5-NOL 30+Fix. A	1.9	89.9
16	H	Greening	6-NOL 30+Fix. A (10-day intervals)	1.0	96.8
17	H	McIntosh	4-NOL 30+Fix. A; 2-oil+nicotine	3.5	93.6
18	H	Greening	3-NOL 30+Fix. A; 2-oil+nicotine	4.9	94.8
19	L	Greening	3-NOL 30+Fix. A+oil; 1-NOL 30+Fix. A	1.6	92.9
20	L	McIntosh	1-LA; 2-NOL 30+Fix. A; 1-oil+nicotine	9.1	93.0
21	L	McIntosh	1-LA+lime; 2-NOL 30+Fix. A; 1-oil+nicotine	4.4	92.5
22	H	McIntosh	1-LA; 2-NOL 30+Fix. A+oil; 3-NOL 30+Fix. A	5.0	86.1
23	H	McIntosh	1-LA; 3-NOL 30+Fix. A+oil; 2-NOL 30+Fix. A	8.5	94.0
24	L	McIntosh	1-NOL 30+Fix. A; 1-ZA; 2-NOL 30+Fix. A	5.0	96.2
25	L	McIntosh	1-NOL 30+Fix. A; 1-ZA+lime; 2-NOL 30+Fix. A	6.0	93.5
26	H	Greening	4-Oil 2 qts.; 1-NOL 30+Fix. A	3.5	87.0
27	H	Greening	3-Oil 2 qts.; 2-NOL 30+Fix. A	2.0	93.5
28	H	Greening	3-Oil 2 qts.+nicotine; 2-NOL 30+Fix. A	2.1	97.6
29	H	Greening	3-Oil 3 qts.; 2-NOL 30+Fix. A	2.6	92.5
30	H	Greening	3-Oil 3 qts.+nicotine; 2-NOL 30+Fix. A	1.1	98.9
31	H	McIntosh	1-LA; 3-oil+nicotine; 2-*B.L. 155*	13.4	92.1
32	H	McIntosh	1-LA; 2-oil+nicotine; 3-*B.L. 155*	7.6	91.8
33	L	McIntosh	1-LA; 2-oil+nicotine; 1-NOL 30+Fix. A	1.0	99.5
34	L	McIntosh	1-LA+lime; 2-oil+nicotine; 1-NOL 30+Fix. A	1.3	98.9
35	H	McIntosh	6 Lead arsenate	29.4	89.4
36	H	Greening	5 Lead arsenate	4.9	99.2
37	L	McIntosh	4 Lead arsenate	4.2	98.9
38	L	Greening	4 Lead arsenate	2.4	97.3
39	L	Greening	4 Zinc arsenate	8.4	84.1

* Numbers preceding the name of a spray indicate the number of cover sprays made with that material.
† Per cent efficiency was based on the number of deep worm-holes in 100 apples.
‡ L = light infestation, approximately 18 worms in 100 apples.
H = heavy infestation, from 80 to 100 worms in 100 apples.
Abbreviations:
B.L. 155 = *Black Leaf 155*
NOL 30+Fix. A = Tank mixed nicotine bentonite.
LA = Lead arsenate
ZA = Zinc arsenate

were close to that of lead arsenate (plats 35 to 38). Zinc arsenate when used continuously through the cover sprays appeared to be inferior to both nicotine and lead arsenate (plat 39). This arsenical, however, proved to be a valuable non-lead spray for use in the lighter infested plantings.

The tank mixed nicotine bentonite spray left a heavy, conspicuous residue on the picked fruit, while the *Black Leaf 155* showed as a very light deposit. During most seasons it is desirable to use a fungicide in the last cover spray to avoid late season infections of apple scab. Sulfur used in these late applications in combination with the nicotine sprays noticeably increased the visible residue. However, spray deposits were easily removed with a brush or other mechanical cleaner.

The figures given for plats 4 to 11 are the results of tests with the *Black Leaf 155*

used in various combinations with other spray materials.

By using lead arsenate in the first cover spray, or lead arsenate in the first followed by zinc arsenate in the second cover, or zinc arsenate in the first two cover sprays and finishing the remainder of the schedule with a nicotine mixture, it was possible to secure commercial control of the codling moth and, at the same time, keep within the tolerance limits for lead and arsenic.

The combination of 4 pounds *Black Leaf 155* with 2 or 3 quarts of summer oil made a very efficient spray and at a lower cost than 8 pounds of *Black Leaf 155* without oil. The oil, in addition to its value as an ovicide, tended to mask the light residue left by the nicotine spray, thereby avoiding a cleaning operation. Experience has shown that summer oils should be used with discretion for the reason that too large amounts of oil or too many applications tend to dull the finish and retard the natural coloring of the fruit.

Tests with the modified *Black Leaf 155* (plat 12) failed to indicate any advantage over the *Black Leaf 155*.

Plats 17 to 25 are examples of various combinations of tank mixed bentonite, lead arsenate, zinc arsenate and oil nicotine, the residues from which were within the tolerance limits for lead and arsenic. Similar to the *Black Leaf 155*, nicotine bentonite used with summer oil made a very efficient spray for controlling the codling moth, and the presence of the oil noticeably reduced the amount of visible residue.

Chemical analyses have shown that hydrated lime when used in combination with fixed nicotine sprays tended to liberate about 90 per cent of the nicotine that would otherwise have remained as fixed nicotine. This raises the question as to the effect of hydrated lime on fixed nicotine sprays when used in applications preceding the nicotine. The nicotine treatments on plats 21, 25 and 34 were preceded by applications of lead arsenate or zinc arsenate with hydrated lime. Comparison of the treatment efficiencies in these plats with those of 20, 24 and 33 indicate little or no appreciable influence of the lime on the efficacy of the treatments. Three pounds of hydrated lime were used in each 100 gallons on plat 25 and one-half this amount on plats 21 and 34.

For the past several years the combination of summer oil with nicotine sulfate has been one of the most reliable and efficient fixed nicotine sprays. Its use is limited, however, to two or three applications because of the undesirable results that follow the excessive use of oil. To make comparisons of the value of oil and oil plus nicotine treatments, the remainder of the summer spray program was completed in each case with *Black Leaf 155*.

Plats 27 and 29 compared with 28 and 30 give the value of oil sprays when used alone and when combined with nicotine. There apparently was little difference in control resulting from the use of 2 and 3 quarts of oil in 100 gallons, but the addition of nicotine sulfate raised the efficiency of the treatment noticeably. A schedule in which one application of lead arsenate was followed by two or three sprays of oil plus nicotine and the program completed with *Black Leaf 155* not only was very efficient in combating the worms but left very little residue on the fruit.

Applications of sulfur to prevent apple scab, when applied following treatment with summer oil, caused considerable foliage injury on Greenings. The amount of injury was influenced by the number of oil treatments and the time elapsing between the oil and the sulfur applications. Elemental sulfur used two weeks following the last of four one-half per cent summer oil sprays caused from 30 to 50 per cent defoliation. When applied four weeks after a third application of three-fourths per cent oil, Greening trees lost from 25 to $33\frac{1}{3}$ per cent of their foliage. A four-week interval between a second spray of one-half per cent oil and the time sulfur was applied caused little or no appreciable leaf drop. The foliage of McIntosh appeared to be less susceptible to this type of injury.

SUMMARY.—Two commercially prepared nicotine sprays, namely *Black Leaf 155* and a *tank mixed nicotine bentonite spray*, gave satisfactory control of the codling moth in orchard tests. The *Black Leaf 155*, when used in three cover sprays, left a light residue that was usually negligible in amount at picking time. With five and six applications a light

visible residue remained on the harvested fruit. Summer oil when combined with *Black Leaf 155* was a very efficient spray and at the same time rendered the visible residue less conspicuous. The tank mixed nicotine bentonite spray left a heavy deposit that required cleaning. All residues from these nicotine sprays were easily removed with a brush cleaner.

Nicotine sprays gave noticeably better control when the interval between applications did not exceed ten days than when longer periods of time were allowed between treatments.

Hydrated lime incorporated in the spray preceding an application of fixed nicotine apparently had little effect on the efficiency of the nicotine treatment in lightly infested orchards.

Defoliation occurred on certain plats as a result of an application of sulfur following earlier treatments with summer oil. The degree of injury in each case was influenced by the variety of apple, the amount of oil that was used and the time elapsing between the final oil treatment and the application of the sulfur.—12-17-37.

Leafhopper Migration Across Delaware Bay

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The information summarized herein was secured incident to a study of mosquito migration across Delaware Bay, the results of which have already been published (MacCreary & Stearns 1937). A map of the area in question, illustrations covering the trap locations and a full statement of the procedure involved were included in that report.

LIGHT TRAPS.—In this paper, therefore, it seems sufficient to state that the light traps, which were installed on four of the five lighthouses that mark the ship channel in the approximate center line of the Bay were, with but one exception, in continuous operation during the months of May to September, inclusive, 1936. Wind directions for both evening and morning were recorded at all trap locations, and additional data covering precipitation and other weather phenomena at two of the lighthouses.

The Ship John Shoal, Elbow of Cross Ledge, Fourteen-Foot Bank and Brandywine Shoal lighthouses are 3, 6, 9 and 10 miles, respectively from shore. In each case, except Fourteen-Foot Bank, the white sector of the light beam is toward Delaware and the red, toward New Jersey. Although these several lights have varying characteristics for identification by shipping, the beams of all of them are visible from a point 15 feet above sea level for a distance of 14.9 miles.

It is possible that the number of insects captured was somewhat influenced by the attraction set up by the illuminating apparatus of the lighthouses, which may have tended to create more or less of a concentration in the immediate vicinity. However, when it is considered that all of the traps were from 20 to 30 feet above low water and in entirely unprotected situations, in contrast to those that obtain on land, the magnitude of insect flight across the upper reaches of the Bay, as emphasized by the data recorded, may be better visualized.

LEAFHOPPERS COLLECTED.—Records of the leafhoppers collected are presented in table 1. In all, 3466 specimens representing 33 genera and 50 species were captured. The female leafhoppers far exceeded the males in number, the percentages of the entire catch being 70.5 and 29.5, respectively. The data for Ship John Shoal lighthouse (3 miles from shore) show that 60.1 per cent of the total material collected was obtained at that point, while the percentages for Elbow of Cross Ledge, Fourteen-Foot Bank and Brandywine Shoal (26.5, 7.2 and 6.2, respectively) are considerably and progressively lower, as would be expected with the increasing distance from land.

An examination of the list of species, considered in terms of leafhoppers attacking cultivated crops, makes it immedi-

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ately apparent that for the most part those included are non-economic in character. Literature on this group indicates that the majority of them normally occur on and are collected from various trees, shrubs and grasses growing under conditions that approach somewhat their natural state. The notable exceptions are, of course, *Agallia constricta*, *Draeculacephala mollipes*, *Polyamia inimicus*, *Thamnotettix nigrifrons*, *Cicadula divisa* and *Empoasca fabae*. Their economic importance is well established. Grasses and grains support large populations of *A. constricta* and the four species next mentioned. Claassen (1933) recorded injuries of a type not heretofore reported on apples caused by the oviposition punctures of *D. mollipes*. Both twigs and fruit were thus damaged in orchards in which the ground was well covered with grass and weeds. *E. fabae* is known as a destructive potato pest and occurs frequently in great numbers on many other hosts. In view of the considerable acreage devoted to intensive farming in both Delaware and New Jersey, the absence from these collections of such common leafhoppers as *Empoasca*

Table 1.—Records of leafhoppers collected on lighthouses in Delaware Bay, 1936.

Genus	Species	Number of Leafhoppers Collected						
		Ship John Shoal	Elbow of Cross Ledge	Fourteen-Foot Bank	Brandywine Shoal	Male	Female	Total
Agallia	*constricta* V.D.	62	24	7	55	50	98	148
Idiocerus	*nervatus* V.D.	2	2		1	1	4	5
Idiocerus	*pallidus* Fh.		1			1		1
Idiocerus	*alternatus* Fh.	4	16	2	13	15	20	35
Idiocerus	*lachrymalis* Fh.	1	1				2	2
Bythoscopis	*apicalis* (O. & B.)	5					5	5
Kolla	*bifida* (Say)	4	1			2	3	5
Graphocephala	*versuta* (Say)	1					1	1
Draeculacephala	*mollipes* (Say)	19	2	5	2	9	19	28
Carneocephala	*flaviceps* (Riley)	1			1	1	1	2
Gypona	*octolineata* (Say)	1					1	1
Zestocephalus	*pulicarius* V.D.	8	3	6	2	11	8	19
Zestocephalus	*superbus* (Prov.)	6					6	6
Spangbergiella	*vulnerata* (Uhl.)	1					1	1
Parabolocratus	*flavidus* Sign.	4	1	1			6	6
Sanctanus	*cruciatus* Osb.	1					1	1
Sanctanus	*aestuarium* DeL. & Slees.	46				1	45	46
Osbornellus	*auronitens* Prov.	1				1		1
Scaphoideus	*immistus* (Say)	11	3			8	6	14
Platymetopius	*acutus* (Say)	1				1		1
Polyamia	*interruptus* DeL.	1					1	1
Polyamia	*inimicus* (Say)	13	7	3	1	7	17	24
Laevicephalus	*littoralis* Ball	6	2	1	1	1	9	10
Amplicephalus	*simplex* V.D.	616	65	2	1	236	448	684
Deltocephalus	*flavicosta* Stal.	18	1	3	2	9	15	24
Exitanus	*obscurinervus* Stal.	2			1	1	2	3
Drylix	*striolus* (Fall.)	6	15	24	1	11	35	46
Ophiola	*striatulus* (Fall.)		3		1	2	2	4
Norvellina	*seminudus* (Say)	6	11	8	3	12	16	28
Norvellina	*chenopodium* Osb.				1	1		1
Phlepsius	*majestus* O. & B.	1					1	1
Phlepsius	*irroratus* (Say)	12	8	6	1	15	12	27
Phlepsius	*collinus* Osb. & Lath.				3	2	1	3
Phlepsius	*torridus* Lath.		3		1		4	4
Phlepsius	*collitus* Ball		2	3	1	2	4	6
Phlepsius	*nebulosus* V.D.	3	17		20	18	22	40
Phlepsius	*solidaginis* (Walk.)	1					1	1
Dolcanus	*perspicillata* O. & B.	1					1	1
Graminella	*fitchii* V.D.	1					1	1
Graminella	*plana* DeL.	9	2	4		8	7	15
Graminella	*bisignatus* DeL.	313	8		5	123	203	326
Thamnotettix	*nigrifrons* (Forbes)	292	518	59	56	212	713	925
Chlorotettix	*viridius* V.D.	43	25	9	18	24	71	95
Chlorotettix	*tunicatus* Ball			1			1	1
Cicadula	*variata* (Fall.)	1	1				2	2
Cicadula	*divisa* (Uhler)	517	139	56	3	172	543	715
Balclutha	*abdominalis* (V.D.)		1			1		1
Agellus	*neglectus* DeL. & Dav.				1		1	1
Forcipata	*loca* DeL. & Cald.	5	7	28	2	15	27	42
Empoasca	*fabae* (Harris)	37	29	23	17	50	56	106
Totals 33	50	2083	918	251	214	1023	2443	3466
Per cent of total leafhoppers collected		60.1	26.5	7.2	6.2			100.0
Distance in miles from shore		3	6	9	10			
Number and per cent of male leafhoppers		661–31.7	224–24.4	69–27.5	69–32.2	29.5		100.0
Number and per cent of female leafhoppers		1422–68.3	694–75.6	182–72.5	145–67.8		70.5	

maligna (Walsh), *Typhlocyba pomaria* McAtee, *T. rosae* (L.), *Erythroneura comes* (Say), *T. hartii* (Gill.) and *T. tricincta* Fitch is surprising.

MOST NUMEROUS SPECIES.—Seven species occurring in numbers of approximately 100 or more comprise 86.5 per cent of the total leafhoppers collected. They are listed herewith in order of relative abundance: *Thamnotettix nigrifrons* (26.7 per cent), *Cicadula divisa* (20.6 per cent), *Amplicephalus simplex* (19.7 per cent), *Graminella bisignatus* (9.4 per cent), *Agallia constricta* (4.3 per cent), *Empoasca fabae* (3.1 per cent) and *Chlorotettix viridius* (2.7 per cent). Four of them have already received consideration. *Amplicephalus simplex* is a leafhopper commonly present during midsummer on salt meadow cordgrass (*Spartina patens*) and on salt grass (*Distichlis spicata*) in tidewater flats along the Atlantic Coast from Connecticut to Virginia. Although it was collected in large numbers, but 10 specimens of *Laevicephalus littoralis*, a somewhat closely related form occurring on the same plants, were captured.

The data for *Graminella bisignatus* are of considerable interest. In all, 326 individuals were secured, 235 of them on a single night. This species was described by DeLong from two specimens collected at Cleveland, Florida. He has never been able to take it in the field, although it comes to lights very readily. He further states that it is undoubtedly a salt marsh species, but that its food plant is still unknown. The dominant vegetation along the bay shore near the present point of collection is salt marsh cordgrass (*Spartina alterniflora*).

Chlorotettix viridius is a rather common leafhopper, representing a genus whose members live in moist locations and feed upon sedges and swamp grasses.

The several species just referred to were collected at all trap locations and were present almost continuously throughout the summer. Although they appeared usually in small numbers, there were occasional nights on which conditions were favorable when substantial flights were recorded.

LESS ABUNDANT SPECIES.—Information concerning the less abundant species is naturally incomplete and the data contradictory when an attempt is made to draw conclusions based upon either the point of collection or the period of occurrence. For example, in most instances the larger leafhoppers appeared in the collections for the two lighthouses, 3 and 6 miles, respectively, from shore. Yet *nebulosus*, one of the more robust species of the genus *Phlepsius*, was recorded in greatest numbers at Brandywine Shoal, the most distant point from land.

MOVEMENT OF LEAFHOPPERS.—The traps collected leafhoppers over a period of 144 days from May 8 to September 28, inclusive. They were present on 92 days (64 per cent) and absent on 52 days (36 per cent). The records for the 3466 leafhoppers captured show that 78 per cent of them were taken on 56 days (61 per cent) in which the wind was from the direction of Delaware and that 22 per cent were collected on 36 days (39 per cent) in which the wind was from the New Jersey shore. These data indicate a ratio between eastward and westward movement of leafhoppers of approximately 4 to 1 as compared with that of approximately 7 to 1 previously reported for mosquitoes and based upon 57,145 records. In the above calculations, wind records obtained on the lighthouses throughout the period the traps were in operation were utilized. They are in agreement with those of the Weather Bureau for 1936, which show that, as usual, the prevailing wind for this area was from the southwest during the months of May to September, inclusive.

The nights on which no leafhoppers were trapped occurred usually in groups in which there was definite interference with activity by weather—low temperature primarily, and, to a lesser extent, cloudiness, strong winds and rainfall. The daily mean temperature for the entire period (data for Dover, Del.) was 72.1 degrees F. On the nights on which no collections were made the temperature averaged 68.0 degrees F.; on the nights with collections of from 1 to 100 leafhoppers, 73.5 degrees F.; and on the nights with collections of more than 100 leafhoppers, 82.2 degrees F. During the course of the summer, there were 9 nights (June 3 and 15, July 9, 10, 15 and 16, August 22 and 23 and September 9) when large flights were recorded. These peaks were definitely associated with the following combination of factors: a high mean temperature, a clear night and, with but

one exception (June 3), a light to moderate wind from the Delaware shore.

In addition to the conclusions already drawn during the presentation of these data, the fact may well be emphasized that records of this kind indicate clearly that a great natural barrier, such as the Delaware Bay, is in reality but a slight hindrance to insect migration when conditions are favorable for it.—12-17-37.

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Ecological Studies of the White Apple Leafhopper, *Typhlocyba pomaria* McAtee

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In leafhopper studies in Virginia orchards, the white apple leafhopper, *Typhlocyba pomaria* McAtee, has been observed to be more numerous on the foliage of trees in sprayed orchards than on that of trees in unsprayed orchards, or on that of isolated unsprayed trees. There is usually a great difference in the numbers of leafhoppers in different orchards and in different localities, but leafhoppers are generally most numerous in the orchards that are in a high state of cultivation, where pruning, spraying and the use of fertilizers are regularly practiced. This condition was thought to be due, in part, to the succulency of the twigs and the foliage (Schoene 1932).

The relative injury to the foliage of the sprayed and of the unsprayed trees is indicated by the leaves in fig. 1. These leaves were collected on October 12, 1937. The leaf on the right was taken from a back-yard tree of the Stayman Winesap variety, while the other leaf was taken from a tree of the same variety in the college orchard. The trees are slightly more than a mile apart. The foliage on the back-yard tree was badly injured by frogeye leafspot and scab, but there was very little stippling by leafhoppers. The foliage on the trees in the college orchard showed very little evidence of injury by fungous diseases but it was severely injured by leafhoppers, so much chlorophyll having been removed that the leaves had a grayish appearance. This was true of the foliage of all the trees in the college orchard at the time the leaf shown in the figure was collected. In making examinations of foliage, it was often impossible to find a single leafhopper on an unsprayed tree, and at most only a few individuals were present. On sprayed trees, however, these insects were generally present and were often found in large numbers. It is apparent that the conditions in a sprayed orchard are favorable for leafhoppers. It is believed that the spray materials have a protective influence on their development.

FIG. 1.—The leaf on the left shows the leafhopper injury to foliage on a sprayed tree, and the leaf on the right the injury on an unsprayed tree.

REARING LEAFHOPPERS ON SPRAYED FOLIAGE.—To study the effect of sprayed foliage on leafhopper development, controlled experiments were planned in which leafhoppers were placed on small trees that had been sprayed previously with one or more of the common insecticides. In table 1 are shown the results of a series of experiments for the years 1934 to 1937.

The method employed in carrying out these tests was as follows: The trees were planted in pots during the dormant season, and the pots were set in soil. They were left outdoors until the foliage had developed and the adult leafhoppers were available for the experiment. The potted trees were then moved to the insectary and the sprays were applied with a hand atomizer. After the foliage had thoroughly dried, each tree was enclosed in a large lantern globe, provided with ventilators at the top and the bottom. The adult leafhoppers were collected from trees were sprayed on June 12, and from 12 to 20 females per plant were added between June 13 and June 23, inclusive. The second spray was applied on July 18 and 19; and the third, on August 3. In 1935 the trees were sprayed and the leafhoppers were placed on the foliage on July 1 and 2, 10 females being placed on each plant. The trees were sprayed only once in the 1935 experiment. In 1936 the sprays were applied on June 11, and the leafhoppers were placed on the foliage between June 17 and 20. The trees were sprayed only once during this experiment.

Table 1.—Results of rearing leafhoppers on sprayed, potted apple trees in the insectary at Blacksburg, Virginia.

TREE NO.	MATERIALS USED*	NUMBER OF NYMPHS AND ADULTS PRODUCED			
		1934 Sprayed Three Times	1935 Sprayed Once	1936 Sprayed Once	1937 Sprayed Twice
1	Bordeaux	2	172	171	0
2	Bordeaux	—	138	586	2
3	Lead arsenate, 1½ lbs.	64	202	377	—
4	Lead arsenate, 1½ lbs.	—	—	475	4
5	Bordeaux, lead arsenate, 1½ lbs.	0	99	175	18
6	Bordeaux, lead arsenate, 1½ lbs.	0	—	403	48
7	Lime sulphur, 5 qts.	110	505	328	27
8	Lime sulphur, 5 qts.	—	—	236	61
9	Lime sulphur, 5 qts.; lead arsenate, 1½ lbs.	10	14	149	12
10	Lime sulphur, 5 qts.; lead arsenate, 1½ lbs.	7	—	145	89
11	*Coposil*, 1½ lbs.	—	49	102	54
12	*Coposil*, 1½ lbs.	—	—	309	63
13	*Cal-Mo-Sul*, 3 lbs.	—	311	87	48
14	*Cal-Mo-Sul*, 3 lbs.	—	—	406	33
15	*Coposil*, 1½ lbs.; oil, 1%	—	—	161	92
16	*Coposil*, 1½ lbs.; oil, 1%	—	—	133	7
17	*Cal-Mo-Sul*, lead arsenate	—	235	—	—
18	Check	40	569	293	137
19	Check	—	181	304	—

* All amounts mentioned are for 50 gallons. In 1937 a 4-4-50 Bordeaux was used, while in the other years the formula was 2-4-50.

apple trees and placed in the lantern globes. It was not always possible to place an equal number of individuals on the plants, but approximately the same numbers of males and females were used. The adults were left on the plants during the oviposition period. The lantern globes were then removed and allowed to remain off through the incubation period and until the next brood of nymphs appeared. When more than one spray application was given, the second and third applications were made during the incubation period.

RESULTS OF THE EXPERIMENT.—The results of the laboratory work for the four seasons are given in the table. In 1934 the Ten females were placed on plants no. 11 and 12 and 15 to 19, inclusive. The other plants had 14 females each. The results should indicate the influence on the feeding and oviposition of adults. In 1937 the trees were sprayed on June 8, and the insects were caged June 9 to 14, 10 females to each plant. On July 24 the lantern globes were removed and the trees were sprayed again with the same materials as before.

SIGNIFICANCE OF THE EXPERIMENT.—These experiments show the extent to which the feeding and the oviposition are influenced when the adults are placed on foliage heavily coated on both sides with sprays. The experiments for 1934 and

1937 show also the effect of the sprays upon the development when they emerge from foliage which has been recently sprayed.

In 1934 and 1935 tests were conducted similar to the one mentioned above, except that very small nymphs, usually first or second stage, were placed on heavily sprayed foliage. The detailed data for these tests are not included, but they indicated that foliage heavily coated with Bordeaux or with Bordeaux and lead arsenate had an unfavorable effect on the leafhopper nymphs.

Difficulty was experienced in growing apple trees in pots, especially when the foliage was enclosed in lantern globes. The lantern globes tended to exclude the air and make conditions favorable for mildew and red spider so that certain trees in the experiment were often damaged by these pests to the extent that the foliage did not furnish suitable food for leafhoppers.

By examination of the table it will be seen that, when adults were placed on the freshly sprayed foliage, the insects deposited as many eggs as did those on unsprayed check trees. When the trees were sprayed only once, that is, before the eggs were deposited, the number of nymphs developing on the sprayed foliage equalled the number on the check. In 1936, for instance, 757 nymphs, which were the progeny of 28 females, were produced on two trees sprayed with Bordeaux. There developed on the two check trees 597 nymphs, the progeny of 20 females. Two or more applications of spray material apparently had the effect of reducing the number of nymphs. It is believed, however, that the materials commonly used in apple orchards, in the quantity applied, would have very little effect upon the feeding and the oviposition of the white apple leafhopper, for when the second brood nymphs emerge in August the spraying season is past. Since the Bordeaux alone and the Bordeaux with lead arsenate as used in these experiments seem to have reduced the numbers of leafhoppers in the years 1934 and 1937, these materials should be tested further before definite conclusions are drawn.

EFFECT OF SPRAYS ON INSECT PARASITES OF WHITE APPLE LEAFHOPPERS.—Two insect parasites of the white apple leafhopper have been previously reported, one, an egg parasite, *Anagrus armatus* (Jordan 1918), and the other, a dryinid which parasitizes the nymph and completes its development in the adult. On different occasions these parasites have been observed in considerable numbers. As previously noted (Schoene 1930) in several collections, as many as 70 per cent of the adults were parasitized by the dryinid. At another time, many of the wintering eggs were observed to be parasitized by the egg parasite. No information as to the effect of sprays on these insect parasites is available.

EFFECT OF SPRAYS ON FUNGOUS ENEMIES OF WHITE APPLE LEAFHOPPER.—In 1935 leafhoppers which had been killed by a fungus were found in several sections of the state. This fungus was identified as *Entomophthora sphaerosperma*, and its occurrence reported (Wingard 1936). In that year a heavy rainfall occurred during the first week in September, and leafhoppers parasitized by this fungus were noted September 24. The diseased leafhoppers were observed in a number of orchards but were conspicuous in only two, which were widely separated. The fungus appeared suddenly in these two orchards. A heavy infestation of leafhoppers was present; and, after the appearance of the fungus, the living insects largely disappeared, leaving several dead individuals on each leaf, 10 to 15 being occasionally found. In 1936 the weather was dry and, although frequent searches were made in the different orchard sections, no diseased leafhoppers were seen.

In 1937 the weather was variable but the rainfall was generally heavier than for several years. This was especially true in the central part of the state and in the vicinity of Blacksburg. In September and October of this year, the insects killed by the fungus were very evident in certain orchards in Albemarle County, and in Augusta County and in the college orchard at Blacksburg. It was not unusual to find from 1 to 4 dead leafhoppers per leaf, and occasionally as many as 12 or 15 were found.

During the summers of 1935, 1936 and 1937, many orchards were examined in an effort to learn more about the distribution of the fungus and the conditions favorable to it. The diseased insects were found only where leafhoppers were present in large numbers. Heavy and frequent

applications of Bordeaux seem to have prevented the appearance of the leafhopper fungus. Thus far the fungus has been observed only following a prolonged wet spell in a few orchards in which spray applications were discontinued early in the season.

SUMMARY.—The white apple leafhopper is usually abundant only in sprayed orchards and especially on the more succulent, rapid growing apple varieties, such as Stayman Winesap and Delicious. It appears that the sprays commonly used in orchards for the control of orchard insects and diseases have very little direct influence on the feeding and oviposition. No evidence is at hand as to the effect of spray mixtures on the insect parasites of the white apple leafhopper. Under certain conditions, the insect is parasitized by a fungus. In 1935 and 1937 this fungus greatly reduced the number of leafhoppers in certain orchards; but field observations indicate that this fungus is held in check by applications of lime sulphur early in the season and by heavy and repeated applications of Bordeaux late in the season.—12-17-37.

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Effects of Orchard Practices on Natural Enemies of the White Apple Leafhopper[1]

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During an investigation of the biology and control of the white apple leafhopper, *Typhlocyba pomaria* McAtee, in the Hudson Valley, it has been possible to study the natural enemies in various types of orchards and in similar plantings where different horticultural practices have been followed. Within each of the five years from 1933 to 1937, inclusive, these orchards have harbored leafhopper populations ranging from less than 10 to more than 1000 leafhoppers per 100 leaves. While natural enemies and weather conditions are believed to limit the number of leafhoppers in this region as a whole, observations have indicated that local environment, tree vigor, orchard practices and their effects on the natural enemies contribute largely to the population differences existing between orchards.

Although it has not been difficult to kill leafhopper nymphs with contact sprays, there have been some indications that these sprays, if applied indiscriminately, may by their effects on the natural enemies increase rather than reduce the problems of controlling the leafhopper in this area. Sprays applied for other orchard pests have previously been thought to affect the natural enemies of the leafhopper. Garman (1934) has expressed the opinion that early sprays reduced the number of natural enemies, whether or not they killed leafhoppers. According to Garman & Townsend (1936), the natural control of the white apple leafhopper has been so successful in Connecticut that unsprayed trees are rarely if ever seriously harmed. More recently, Schoene (1938) has had reason to believe that heavy and frequent applications of fungicides in Virginia orchards have prevented the appearance of a leafhopper fungus, *Entomophthora sphaerosperma*, that had been observed following a prolonged wet spell in orchards where spray applications were discontinued early in the season.

Many of the orchards under observation in the present study received most of the fungicidal and arsenical sprays recommended for the Hudson Valley up to the first codling moth cover spray. Some received a second cover spray and some had sprays applied for leafhoppers. Within

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these plantings, the parasitism of overwintering eggs by the mymarid, *Anagrus armatus* Ashmead variety *nigriventris* Girault, ranged from a minimum of 68 to a maximum of 96 per cent, while the total parasitism of eggs in foliage ranged from only 5 to 63 per cent. The parasitism of white apple leafhoppers by the bethylid, *Aphelopus typhlocybae* Muesebeck, ranged from 1 to 74 per cent in the same generation and exceeded 80 per cent in a few orchards in other seasons. The mirid predator, *Diaphnidia pellucida* Uhler, which also preys on other apple leafhoppers, aphids, and the European red mite, as well as on others of its own species, was found to exceed 12 per 100 leaves in certain orchards while being extremely scarce in others. *Hyaliodes vitripennis* Say, and other Hemiptera, chiefly mirids and reduviids, were less common and were regarded as incidental predators.

Many small spiders, of which one species has been identified as *Araneus thaddeus* Hentz, were common and may have reduced the leafhopper population to some extent. Fungous growths and small mites have been observed on the bodies of leafhoppers killed by *Aphelopus* as well as on hoppers reared in cages at high humidities, but they have not been a factor in the control of the leafhopper in sprayed orchards during the interval of this study.

LIFE CYCLE RELATIONSHIPS

It should be noted that the life histories of the leafhopper and its parasites differ in relation to tree development and to each other in different localities. Thus Chapman *et al.* (1932) observed that hatching of first brood nymphs in the Hudson Valley and in western New York was closely parallel when dates were compared but earlier in western New York than in the Hudson Valley when compared with bud development. The report of Armstrong (1935) indicated that hatching of the first brood hoppers in Ontario was similar to that in western New York where hatching was complete at the time of the calyx spray. Armstrong also reported hatching and egg deposition of second generation leafhoppers much earlier than either occur in the Hudson Valley. Dumbleton (1934), who studied the yellow apple leafhopper, *T. australis* Froggatt, in New Zealand reported the emergence of the egg parasite from host eggs over a much shorter part of the season than occurs from eggs of the white apple leafhopper in southeastern New York. The emergence of the egg parasite from eggs of the latter host, as reported by Armstrong (1936) in Ontario, also extends over a shorter period of the season than in the Hudson Valley. The writer observed adults of *Aphelopus typhlocybae* swarming over the foliage in a Champlain Valley orchard located some 200 miles north of Poughkeepsie during the first week of August, 1935, before any emergence from cocoons had occurred in the Hudson Valley orchards.

WHITE APPLE LEAFHOPPER.—Phases in the development of the white apple leafhopper and of the three natural enemies that have been most numerous in commercial orchards of this area are summarized in fig. 1. During the seasons covered in this study, hatching of the leafhopper from overwintering eggs extended from the first week in May through the second week in June, the peak of hatching occurring always during the fourth week in May. The first adults appeared annually from late May until early June. Egg deposition in petioles, mid-ribs and larger secondary veins of the foliage has been noted from mid-June until early August. The peak of oviposition by adults of the first generation occurs during the first two weeks of July. Nymphs of the second generation hatch from eggs in the foliage from early August to mid-September, the peak of hatching occurring each year during the fourth week of August. The first adults of the second generation appear in late August. Eggs are inserted beneath the bark from mid-September until defoliation of the trees occurs in late October or November. The peak of oviposition is reached during October and may vary greatly in time between orchards.

Anagrus armatus var. nigriventris GIR.—This species overwinters as larvae and pre-pupae within the overwintering host eggs. Those individuals overwintering in the pre-pupal stage emerge as adults in late April and early May just prior to the beginning of leafhopper hatching. A second and much larger emergence of adults from overwintering eggs begins at about the completion of leafhopper hatching and extends from mid-June to mid-July.

Larvae remaining within the overwintering eggs in mid-July are full grown and quiescent. They are by far most numerous in branches located within a few feet of the ground and show no further development until early September, when they begin transforming to pupae and adults and emerge during September and October. The cause of this delayed emergence is not known, but where it occurs it insures the maintenance of the species in the orchard if individuals attacking eggs of the first generation in the foliage ing eggs available in the foliage, and the percentage of eggs parasitized is again increased. The final emergence of *Anagrus* from the foliage occurs from mid-September until leaf-fall. Adult parasites of the third and final emergence from overwintering host eggs, together with those of the second and final emergence from host eggs in foliage, parasitize the eggs laid in the bark by second generation leafhoppers.

Aphelopus typhlocybae MUES.—Notes on the life history of *Aphelopus* have been

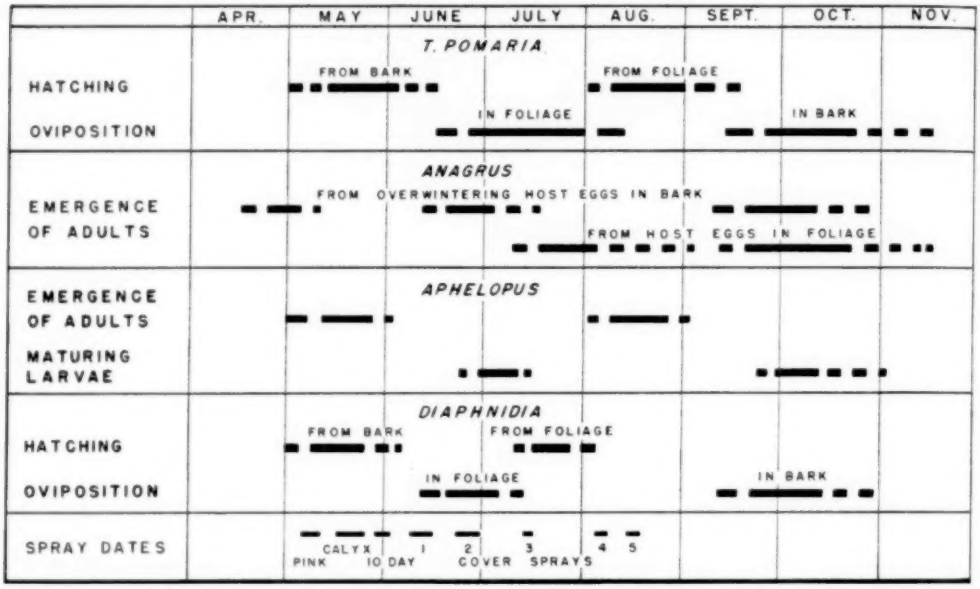

FIG. 1.—Phases in the development of the white apple leafhopper and its natural enemies which are important from the standpoint of control.

are destroyed. The *Anagrus* adults of the second period of emergence from overwintering eggs attack a portion of the leafhopper eggs in the foliage available at the time of their emergence. The parasitism of these eggs in early July has been quite high, 82 per cent in one orchard on July 1, 1936, and 65 per cent in another orchard on July 2, 1937.

However, later egg deposition by the leafhopper greatly lowers the percentage of eggs parasitized. Adults emerge from the first eggs parasitized in the foliage from mid-July until September, with the peak falling in late July to early August before any leafhoppers of the second generation have hatched. These parasites in turn parasitize a portion of the remain-

published by the writer (1936). This bethylid lays its eggs in the leafhopper nymphs, the larvae later appear and mature on the host adults and spin their cocoons in the soil. Adults emerge in May and become most numerous in the orchard just preceding or during the peak of leafhopper hatching, but are exceedingly scarce before hatching is complete. The earlier hatching nymphs are most heavily parasitized. The larval sacs appear on the host adults during June, and the larvae mature in late June and early July. Adults of the second generation emerge from cocoons in the soil during August and are again most numerous on the trees during the earlier stages of leafhopper hatching. Larval sacs appear on

the hosts during September, and the larvae mature in late September and October. Mature larvae of the first generation left the hosts in greatest numbers on July 4 for three successive seasons and parasitized leafhoppers of the first generation have been extremely scarce after July 10. The development of larvae of the second generation may be greatly retarded by low fall temperatures, the larvae then leaving the hosts over a longer period of time than those of the first generation.

Diaphnidia pellucida UHLER.—The hatching of *Diaphnidia* from overwintering eggs in the bark of apple occurs during May. Adults appear during June and oviposit in the foliage from mid-June to mid-July. Hatching of nymphs of the second generation extends from early July to early August. Adults of the second generation appear during August and oviposit in the bark from mid-September to late October. Newly hatched nymphs feed mostly on all stages of the European red mite but the older nymphs and adults appear to prefer leafhoppers when they become available.

EFFECT OF ORCHARD PRACTICES

REMOVING WATERSPROUTS.—Leafhopper adults of the second generation have shown a marked tendency to oviposit in vigorous growth. However, relatively few eggs are laid in the wood of the current season's growth. While eggs may be found in the bark on wood of all ages in a vigorous tree, they are usually most numerous in the bark of two to eight year old wood. In the young and vigorous orchards the number of eggs in watersprouts not of the current season's growth has been found to be about equal to the number in branches of the same length and diameter, whereas in old and less vigorous orchards the number of eggs in watersprouts has been many times greater than in other branches of equal size.

Where the leafhoppers have oviposited to a greater extent in watersprouts than in other branches, the parasitism by *Anagrus* has been lower. Thus, in the orchards reported in table 1, the number of eggs laid per square inch of bark surface in watersprouts of all but the current season's growth in orchards of low vigor was greater than in wood of the same length and diameter of other branches, while the percentage of eggs parasitized was lower in watersprouts. In the young, vigorous orchards where the number of eggs laid in watersprouts was more nearly equal to the number in an equivalent area of other branches, the percentage of parasitism was nearly equal in eggs taken from the two sources. It is believed that the lower parasitism of eggs in watersprouts of the older trees is partly due to the distance that *Anagrus* adults must travel to leafhopper eggs after emerging from host eggs of the first generation, which are rather evenly distributed in all but the terminal and cluster-bud leaves of the foliage. Orchards 7 and 8 had been pruned relatively free from older watersprouts. Orchard 16 was of relatively low vigor due to winter injury and a severe

Table 1.—Abundance and parasitism of leafhopper eggs in the bark of watersprouts and other branches.

Orchard No.	Source of Sample	No. of 2-Inch Lengths of Bark Examined	Avg. Diameter of Samples in Inches	Total Eggs Found	No. Eggs Parasitized	No. Eggs Per Square Inch of Bark	Percentage of Parasitism
		Full Grown Orchards of Relatively Low Vigor					
7	Watersprouts	25	6/16	433	345	7.2	79.7
1935	Other branches	25	6/16	77	72	1.3	93.5
16	Watersprouts	17	5/16	530	402	15.1	75.8
1936	Other branches	32	4/16	52	49	1.0	94.2
		Vigorous Young Orchards					
8	Watersprouts	25	5/16	1268	894	25.9	70.5
1935	Other branches	20	5/16	1623	1175	41.6	72.4
2	Watersprouts	25	5/16	585	472	11.9	80.7
1936	Other branches	25	5/16	514	421	10.5	81.9

pruned relatively free from older watersprouts. Orchard 16 was of relatively low vigor due to winter injury and a severe

infestation of scurfy scale. Many watersprouts were present as few had been removed in a portion of the orchard for an interval of two or three years preceding these counts. Leafhoppers had become numerous in the latter orchard during 1936 and increased in numbers during 1937 in the portion of the orchard where watersprouts had not been removed. The foregoing observations suggest that the removal of watersprouts may aid in leafhopper control in certain plantings in that it might eliminate a considerable proportion of the unparasitized eggs of a given tree.

CULTIVATION.—The degree of parasitism of adult leafhoppers in certain cultivated and uncultivated orchards has been recorded by the writer (1936). During 1936 it was possible to obtain additional information on the effects of cultivation in three orchards as recorded in table 2. Each of these orchards was divided into two parts, one cultivated in the spring before the emergence of *Aphelopus* began and the other portion left uncultivated. The orchards were young and producing vigorous growth. Each was moderately to heavily infested with leafhoppers and had suffered injury by second generation hoppers sufficient to warrant spraying during three or more of the immediately preceding years. Cultivation in orchards 1A and 10 was very thorough, while that in 2 left about one-third of the area beneath the trees undisturbed.

While collections of leafhoppers were taken during the period when parasite larvae were making their appearance externally on the hosts, only those taken when the first parasite larvae were maturing are recorded here. However, the parasitism in these orchards was somewhat greater than could be determined by these collections since some of the parasite larvae mature and leave the hosts before others have developed far enough to be visible externally. Collections were made by sweeping a net against the branches of several trees, the collected leafhoppers being preserved in alcohol until they were counted.

Other records have recently been obtained in orchards where cultivation has been discontinued, or confined to the month of June. In these orchards, the percentage of parasitism either increased or remained at a high level until after the leafhopper population declined.

Table 2.—Leafhopper parasitism by *Aphelopus* in cultivated and uncultivated portions of orchards.

SOURCE OF COLLECTION	DATE COLLECTED	PER CENT OF ADULTS PARASITIZED IN ORCHARDS		
		1A	10	2
Entire orchard, 1935	Sept. 28–29, 1935	34	10	20
Portion cultivated in early May, 1936	June 26, 1936	22	4	20
Portion uncultivated in 1936	June 26, 1936	66	20	34
Portion cultivated in early May, 1936	Sept. 27, 1936	18	7	14
Portion uncultivated in 1936	Sept. 27, 1936	43	21	27

EFFECTS OF COMMON INSECTICIDES AND FUNGICIDES.—During May of 1934 and 1935 it was observed that the mirid predator, *Diaphnidia pellucida*, was rarely found in orchards sprayed with lubricating oil emulsions. Examinations of numerous egg scars in the bark showed that few eggs had hatched and those remaining were dead. Population counts of *Diaphnidia* taken in orchards treated with dormant oils are recorded in table 3. The number of nymphs on untreated trees was very much greater than on those treated with lubricating oil emulsion but

Table 3.—Effects of dormant oils on populations of *Diaphnidia pellucida*.

DORMANT TREATMENT	NO. OF LEAVES EXAMINED*	NO. OF *Diaphnidia* NYMPHS	
		Total Found	No. Per 100 Leaves
Orchard 16, 1936.			
3% lubricating oil emulsion	641	15	2.3
3% tar oil emulsion	637	66	10.4
Untreated (check)	639	78	12.2
Orchard 8, 1937.			
3% lubricating oil	500	3	0.6
Untreated (check)	500	36	7.2

* In 1936 examinations made May 11–21 and in 1937 on May 25.

only slightly greater than on those treated with tar oil emulsion.

No toxic effects of dormant oils have been observed on overwintering eggs of the leafhopper or upon the mymarid parasites within them.

During 1937 the effects of early foliage sprays on parasitism by *Aphelopus* were observed as recorded in table 4. No reduction in parasitism was attributed to the use of either lead arsenate or wettable sulfur. In these tests, liquid lime sulfur, which is known to kill the smaller leafhopper nymphs that it hits, is believed to have killed most of the nymphs that hatched during the blossoming period and to have reduced the total percentage of parasitism by killing off these earlier hatching and more heavily parasitized leafhopper nymphs. Since the earlier hatching nymphs have been found to give rise to a greater proportion of males than females, no great reduction in number of eggs laid by leafhoppers of the first generation can be expected from liquid lime sulfur applied up to calyx. Lime sulfur applied in sprays after calyx is seldom used heavily enough to kill many leafhopper nymphs.

Contact sprays applied early in the hatching season may be expected to produce similar and more striking results. When contact insecticides are applied for first brood leafhoppers it would seem more advantageous to delay their use as long as possible in order to permit the first and more heavily parasitized nymphs to attain the adult stage. In this area, the time suggested for sprays for first brood leafhopper nymphs lies between June 10 and 15, when approximately 15 to 25 per cent of the leafhoppers are in the adult stage.

Observations in two orchards during 1936 showed that where the total percentage of parasitism by *Aphelopus* was 52 and 26 per cent, respectively, of the first generation leafhoppers, those hatching up to May 25 were 60 and 45 per cent parasitized while those hatching on and after May 25 were 18 and 7 per cent parasitized, respectively. In the same orchards, where the total percentage of parasitism of the second generation was 55 and 61 per cent respectively, those hatching up to August 25 were parasitized 72 and 83 per cent, respectively, and those hatching on and after August 25 were parasitized 6 and 12 per cent. respectively. Similar results were obtained in one orchard during 1937. In collections covering eight generations of leafhoppers, taken from several orchards when the first *Aphelopus* larvae were maturing, the parasitism of male leafhoppers has exceeded that of the females.

Table 4.—Indirect effects of early foliage sprays on parasitism by *Aphelopus typhlocybae*, 1937.

Materials Used and Rate Per 100 Gallons		Spray Applications				No. Leafhoppers Collected in 500 Sweepings, June 26–27		Percentage Parasitism		
		Pink 5/6	Calyx 5/18	7-Day 5/25	First Cover 6/7	Males	Females	Males	Females	Total
Untreated (check)						91	116	84	27	52
Hydrated lime Lead arsenate	3 lbs. 3 lbs.	X	X	X	X	106	115	79	31	54
Wettable sulfur Wettable sulfur	8 lbs.* 5 lbs.*	X	X	X	X	88	108	78	25	49
Liquid lime sulfur Wettable sulfur	2 gals.* 5 lbs.*	X	X	X	X	27	101	40	18	23
Liquid lime sulfur	2 gals.*	X	X	X	X	25	80	48	10	19

* Plus 3 lbs. lead arsenate and 3 lbs. hydrated lime.

SPRAYS AND NATURAL ENEMIES

TIMING LEAFHOPPER SPRAYS IN RELATION TO NATURAL ENEMIES.—The lowest percentage of parasitism of eggs in foliage has occurred in orchards sprayed for leafhopper nymphs when only a few had

reached the adult stage. Thus during the late hatching season of 1935, in orchard 10 of fig. 2, which was sprayed for nymphs on June 7, 1935, the parasitism of leafhopper eggs in foliage was 22 per cent. In another orchard sprayed four days earlier, on June 3, 1935, the parasitism of eggs in foliage was only 5 per cent. In orchard 8 eggs and thus the degree of parasitism of eggs in foliage by *Anagrus*.

Contact insecticides applied in May killed many of the smaller *Diaphnidia* nymphs, but the larger nymphs and adults were not injured by the minimum concentrations of nicotine sulfate, pyrethrins, etc., necessary to kill leafhopper

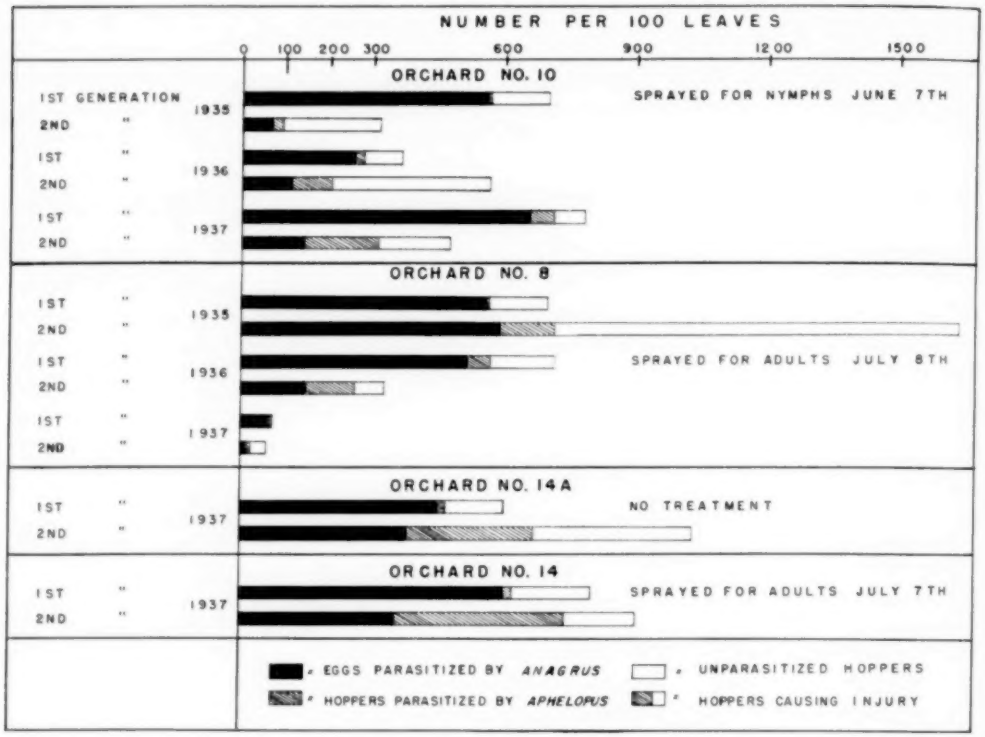

FIG. 2.—Relative populations of leafhoppers in orchards receiving different treatments.

of fig. 2, which was not sprayed for leafhoppers in 1935 but which received the full schedule of sulfur and arsenical sprays up to the second cover, the parasitism of eggs in foliage amounted to 36 per cent. The reduction in parasitism of eggs in foliage sprayed for leafhopper nymphs is attributed to the destruction of leafhoppers which might otherwise have deposited eggs in the foliage before the second emergence of *Anagrus* was completed from overwintering host eggs. Somewhat greater parasitism might have been expected if spray applications for nymphs had been delayed for several days, but heavy early parasitism by *Aphelopus*, regardless of whether sprays are applied for leafhoppers, may also reduce the number of early laid leafhopper nymphs during the second week in June.

An attempt has been made to time sprays for leafhopper adults at periods when the most important natural enemies are protected by their stage or location. It is argued that this method of control would be most applicable to orchards into which considerable migration of leafhoppers occurs. By spraying for adults, it has been possible to maintain a larger reserve of natural enemies after the leafhoppers have been diminished in numbers than when sprays have been applied for nymphs. It has been necessary to delay the sprays for adults until the end of the first week in July in order to protect three natural enemies which have been considered to be of most importance. At this time, most of the *Aphelopus* larvae have

left the hosts, the second emergence of *Anagrus* from overwintering eggs has been nearly complete and most of the *Diaphnidia* eggs have been laid. However, at the same time, approximately 40 per cent of the leafhopper eggs had been laid in 1936 and 65 per cent had been laid in 1937. Consequently, many leafhoppers appeared in the next generation, but their number was less than in similar adjacent orchards which were not sprayed for leafhopper adults.

After several preliminary tests on single trees, pyrethrum was selected for use in spraying entire orchards. Orchard 8 of fig. 2 was sprayed in 1936 with extracts of pyrethrum containing 3 per cent pyrethrins, used at the rate of 1½ pints per 100 gallons of spray with 9 pounds of hydrated lime and 3 pounds of calcium arsenate included for apple maggot protection. Orchard 14 was sprayed in 1937 with ground pyrethrum flowers containing 0.90 per cent pyrethrins, used at the rate of 3 pounds per 100 gallons of spray with 6 pounds of hydrated lime. An 80 to 90 per cent kill was obtained with these sprays estimated from the number of leafhoppers collected in sweepings the day before and the day after spraying. The sprays were applied quickly to all parts of the trees, to weeds beneath the trees and to hedgerows surrounding the orchard. Applications were made with a power sprayer at 400 pounds pressure, a single gun with a three-sixteenths inch aperture being used.

RESULTS OF TIMED SPRAYS.—In orchard 8, the number of eggs laid by leafhoppers declined steadily for three generations following the spray application, and the parasitism by *Anagrus* and *Aphelopus* which increased in the first and remained high in the second generation, following treatment, declined in the third when the population of leafhoppers was at an extremely low level.

In orchard 14, which was observed only through one generation following treatment, the relative number of overwintering eggs which should produce nymphs in 1938 was small and the number of *Aphelopus* larvae in cocoons was large. Orchard 14 is therefore expected to show a further decline in leafhopper population during 1938 similar to that occurring in orchard 8 during 1937.

In constructing fig. 2, the relative number of individuals per 100 leaves was determined as follows: The percentage of parasitism of overwintering eggs attacked by *Anagrus* was determined by dissecting from the bark and counting a large number of eggs before leafhopper hatching began. When hatching neared completion, the average number of leafhoppers per 100 leaves was determined by examining leaves of average size, terminal and cluster-bud leaves excluded. The number of leafhoppers per 100 leaves was considered equal to the number of unparasitized eggs since there is little mortality of unparasitized eggs. The total number of eggs was constructed from this figure by correcting for the percentage of eggs parasitized. The number of leafhoppers parasitized by *Aphelopus* was determined from the percentage of adults parasitized in collections taken when the first parasite larvae matured and left the hosts. The number of individuals per 100 leaves in the second generation was determined by counting and removing the newly hatched leafhoppers at frequent intervals on several marked branches bearing 15 to 25 leaves each, and adding to this the number of parasitized eggs in the foliage. The number of eggs in the foliage, that had been parasitized by *Anagrus*, was determined by examining the foliage after leafhopper hatching was complete. It consisted of the total number of *Anagrus* emergence holes, plus the number of parasites that died before emerging, plus the number of living parasite larvae and pupae still remaining in the eggs at the time the foliage was examined. The number of leafhoppers per 100 leaves parasitized by *Aphelopus* was determined in the same manner as in the first generation.

Sprays applied to nymphs of the second generation have been thought to control the leafhopper more effectively than sprays applied to nymphs of the first generation before hatching is complete. An attempt has been made to determine the effects on the natural enemies of sprays applied for second brood nymphs. In general, it may be said that when these sprays are applied before the completion of hatching, most of the *Aphelopus* parasites are killed through the death of the leafhoppers. When the sprays are delayed until the close of hatching, a portion of the leafhoppers have reached the adult stage, but these are predominately males

and are more heavily parasitized than the remaining leafhoppers. The predator, *Diaphnidia*, is in the adult stage at the time these sprays are normally applied and the adults are not affected by the lower concentrations of insecticides necessary to kill leafhopper nymphs.

Sprays which were tested against leafhopper nymphs of the second generation and which contained nicotine sulfate up to 1 pint per 100 gallons of water used alone, with 3 pounds of soap, or with 1 gallon of summer oil emulsion, as well as sprays with ground pyrethrum flowers containing approximately 1.1 per cent pyrethrins used at the rate of 1 pound per 100 gallons of water, alone, with 2 pounds of soap or with 9 pounds of hydrated lime, have not had an appreciable effect on the egg parasites in the bark or foliage. Furthermore, sprays for second brood nymphs would normally be applied before the final emergence of egg parasites from these sources begins.

SUMMARY AND CONCLUSIONS

The effectiveness of natural enemies in controlling the white apple leafhopper is reduced by certain horticultural practices.

Watersprouts when permitted to grow in abundance in orchards of low vigor may harbor more eggs per unit of surface area than other branches, but the rate of parasitism of eggs in watersprouts is lower.

The population of the predator, *Diaphnidia pellucida*, is reduced by dormant applications of lubricating oil emulsion, which kill the overwintering eggs. *D. pellicida* is also reduced in numbers by applications of contact insecticides if these are applied when the early nymphal stages of the predator are present.

The population of *Aphelopus typhlocybae* is reduced by cultivating beneath the spread of the branches during periods when the parasites are in cocoons in the soil. The population of this nymphal-adult parasite is also reduced by certain sprays which kill leafhopper nymphs, but is apparently not affected by sprays of wettable sulfur and lead arsenate applied during the period when adult parasites are attacking the leafhopper nymphs. When the earlier hatching and more heavily parasitized leafhoppers are killed by contact insecticides and the later hatching nymphs are permitted to reach the adult stage, the percentage of parasitism is greatly lowered.

A spray applied for leafhopper adults at the time when most of the *Aphelopus* larvae have matured and left the hosts, when most of the *Anagrus* adults of the second emergence from overwintering eggs have appeared, and when most of the *Diaphnidia* eggs have been laid, has produced some immediate reduction in the population of leafhoppers of the following generation and permitted a greater reserve of natural enemies to remain in the orchard than when sprays were applied for nymphs.

The percentage of eggs parasitized in the foliage by *Anagrus armatus* variety *nigriventris* appears to be reduced more by sprays which have killed off the earlier hatching leafhoppers of the first generation, and reduced the number of eggs available to the parasites at the time of their emergence, than by subsequent sprays of the standard schedule.

The insecticides tested against leafhopper nymphs of the second generation have had no appreciable effect on *Anagrus* parasites remaining in the foliage or in the bark.—12-17-37.

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Experiments on Rearing Apple Maggot Adults*

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The discovery by Fluke & Allen (1931) of the value of yeast in the diet of the apple maggot adult, *Rhagoletis pomonella* (Walsh), appeared to solve the problem of rearing this hitherto unmanageable species. As part of the investigation of this insect being carried on in eastern New York state, life history studies were attempted, the methods first described by the above authors being used. The results obtained were not satisfactory and it was decided that further study of methods of rearing the flies should be undertaken. Beginning in 1931, this work has been continued each year (with the exceptions of 1933 and 1934) until the present. In all, 188 experiments with different foods and types of cages have been made from which, together with the later modification of their method reported by Allen & Fluke (1933), a fairly successful technique has been evolved.

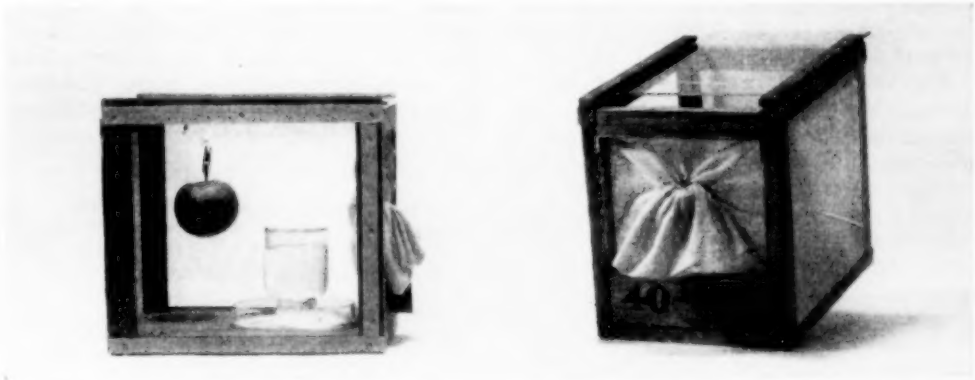

Fig. 1.—Improved rearing cage. The cloth has been removed from one side of the cage on the left to show water bottle and suspended apple.

Materials Used.—The flies used were first generation individuals collected daily from soil emergence cages and transferred to the experimental cages within 24 hours or less from the time of their emergence. Approximately 50 flies, equally divided as to sex, were used in most tests.

Cages of several kinds were tried, including wire-screen cylinders, cloth cages and inverted battery jars as described by Boyce (1934), slightly modified to utilize Fluke & Allen's method of feeding. The most satisfactory type, and the one used in most of these experiments, was a cage 6 by 7 by 8 inches having a wooden bottom and frame, covered with cheesecloth on the sides and one end, the other end being formed by a sleeve and the top by a sliding glass plate, fig. 1. This cage was suitable for the dry-smear method of feeding later recommended.

In the first experiments, food materials were supplied as solutions or suspensions which frequently fermented, causing a heavy mortality unless replaced daily. In all later tests only non-fermentable solutions were used. Sugars and combinations of proteins with sugar were fed by making a thick syrup of the sugar with distilled water, into which the dry, powdered protein was stirred, the resulting mixture then being smeared on the glass top. To replace it, a fresh smear was made on another glass which was then slid into position. The old top was pushed out, but the flies were given no chance to escape. Distilled water and solutions were supplied separately in small, wide-mouth bottles inverted on to filter paper discs in Petri dishes.

Procedure.—Live flies were handled by means of a long glass suction tube which could be slipped through the sleeve without removing the rubber band hold-

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ing it shut. Apples for oviposition were suspended in the cage by means of small spring clips, unripe fruits of the varieties Yellow Transparent and McIntosh being used.

Daily counts were made of the number of dead flies and the number of egg punctures in the fruits. Whenever possible, the punctures were dissected and the number of eggs present determined, for experience has shown that the proportion of punctures to eggs is variable. Many punctures contain no eggs while, conversely, there are not infrequently several eggs in one puncture.

Experiments were run in the insectary with no control of either temperature or humidity and also in a rearing cabinet in the laboratory at 30 degrees C. and 75 per cent relative humidity.

RESULTS WITH PARTIAL AND COMPLETE DIETS.—Results are expressed as the average survival in days, the minimum preoviposition period in days and the average number of eggs produced per female fly surviving the minimum preoviposition period. In the case of replicated experiments, the results, as given in the tables, are the summarized results of all replicates.

Table 1.—Results with partial and complete diets.

MATERIALS FED	AVERAGE NUMBER OF DAYS SURVIVAL	MINIMUM PREOVIPOSITION PERIOD IN DAYS	AVERAGE NUMBER OF EGGS DEPOSITED PER ♀
Control (no food or water)	2.0	—	0
Control*	1.7	—	0
Average	*1.9*	—	*0*
Distilled Water	2.1	—	0
Distilled Water*	2.1	—	0
Average	*2.1*	—	*0*
Dextrose	3.3	—	0
Dextrose*	2.8	—	0
Average	*3.1*	—	*0*
Sugar, Distilled Water	31.5	8	0.65
Protein, Distilled Water	2.4	—	0
Sugar + Non-Protein N, Distilled Water	13.6	14	1.63
Sugar + Protein, Distilled Water	33.7	9	30.41

* Previously fed for 5 days on sugar and water.

In order to maintain life and produce eggs, the flies must have access to a constant supply of water, sugar and a nitrogen-containing food. Lack of either of the first two results in rapid death, even after a previous period of feeding on both. When the flies are supplied with both sugar and water, the length of life is greatly increased but few, if any, eggs are laid. A protein food with water does not sustain life much longer than the control. The addition of a non-protein nitrogen source to sugar and water increases egg production somewhat, while a protein food added to sugar and water greatly increases the number of eggs laid.

RESULTS WITH CARBOHYDRATES.—Of the carbohydrate foods tested, only two, lactose and starch, failed to support life. Two others, sucrose and honey, were distinctly better than the remainder, table 2. It is perhaps significant that they were ordinary, impure commercial products, whereas the others were chemically pure. Although honey was recommended in the original investigators' improved food formula, it was largely abandoned in these experiments in favor of sucrose. The hygroscopic properties of honey made it difficult to maintain in a semisolid form, while its slight protein content complicated tests with other protein foods.

Table 2.—Results with carbohydrates.

MATERIALS FED	AVERAGE NUMBER OF DAYS SURVIVAL	MINIMUM PREOVIPOSITION PERIOD IN DAYS	AVERAGE NUMBER OF EGGS DEPOSITED PER ♀
Dextrose, 5% Solution	12.5	—	0
Dextrose, Distilled Water	34.5	34	0.05
Levulose, Distilled Water	27.4	16	0.21
Sucrose, Distilled Water	36.3	8	1.31
Lactose, Distilled Water	3.0	—	0
Maltose, Distilled Water	29.1	30	0.66
Galactose, Distilled Water	25.6	25	0.12
Honey, Distilled Water	36.0	32	1.55
Starch, Distilled Water	2.2	—	0

The non-protein nitrogenous materials used in the experiment included sodium nitrite and nitrate, ammonium hydroxide and tartrate, ethylamine, urea and the amino-acid, glycocoll. Eggs were produced on all except sodium nitrite, but in small numbers, table 1.

RESULTS WITH PROTEINS.—Under the heading of protein foods are grouped proteid materials, true proteins and materials which are largely protein although containing other food substances in addition, table 3. *Proteose-peptone* and *Bacto-peptone* are dry proteid powders containing proteoses, peptones, polypeptides and amino-acids. Egg albumen and casein are true proteins. Powdered dehydrated brewer's yeast is composed largely of nucleo-proteins, while the dry milk powder contains carbohydrates, fats and salts in addition to protein. Fresh milk was

also used but gave widely varying results. Only casein proved entirely valueless, while *Proteose-peptone* and yeast were outstandingly effective. It will be noted that a mixture of two parts of sugar to one of protein was used. This proportion proved most satisfactory with various sugar-protein mixtures, marked reduction in the number of eggs produced occurring when either more or less protein was fed.

EFFECTS OF INORGANIC SALTS.—The effects of certain inorganic salts in the diet were studied. Secondary potassium phosphate (0.1 per cent) slightly increased egg production when added to either urea or egg albumen, but in other combinations was ineffective. Magnesium sulfate (0.1 per cent), copper, zinc and iron chlorides (0.001 per cent) reduced egg deposition, the last three to a very marked extent. A mixture of calcium, sodium, iron and zinc chlorides, magnesium sulfate and

Table 3.—Results with proteins.

MATERIALS FED	AVERAGE NUMBER OF DAYS SURVIVAL	MINIMUM PREOVIPOSITION PERIOD IN DAYS	AVERAGE NUMBER OF EGGS DEPOSITED PER ♀
Sucrose + *Bacto-peptone* (2-1), Dist. Water	16.4	19	5.26
Sucrose + *Proteose-peptone* (2-1), Dist. Water	24.3	9	53.75
Sucrose + Egg Albumen (2-1), Dist. Water	41.3	15	11.47
Sucrose + Casein (2-1), Dist. Water	9.4	—	0
Sucrose + Yeast Pwd. (2-1), Dist. Water	50.3	9	68.21
Sucrose + Milk Pwd. (2-1), Dist. Water	60.6	13	13.38

secondary potassium phosphate, roughly approximating the inorganic salts found in cow's milk, when added to urea gave the greatest increase. In general, the addition of inorganic salts did not affect oviposition markedly.

EFFECTS OF VITAMINES.—One attempt was made to determine the effects of vitamines other than those occurring naturally in the food. This involved the use of viosterol and proved unsuccessful, the material apparently being toxic.

EFFECTS OF OTHER FACTORS.—In addition to food requirements, other factors have been suggested as influencing egg production in flies. Boyce (1934) expressed the opinion that ultra-violet light stimulated life processes in the walnut husk fly, *Rhagoletis completa* Cress. Accordingly, tests were made by exposing flies in cellophane-covered cages to radiations from a carbon arc. The results were somewhat inconclusive but tended to indicate that the treatment was of no value.

Glaser (1923) reported that unmated houseflies laid fewer eggs than those which had been allowed to mate normally. A similar tendency was apparent in the apple maggot fly, with a marked difference in favor of a sex ratio of 1:1.

Table 4.—Comparison of results in laboratory and insectary.

MATERIALS FED	AVERAGE NUMBER OF DAYS SURVIVAL	MINIMUM PREOVIPOSITION PERIOD IN DAYS	AVERAGE NUMBER OF EGGS DEPOSITED PER ♀
Sucrose + *Proteose-peptone* (2-1), Distilled Water			
Laboratory	26.3	11	165.83
Insectary	21.9	9	49.32
Average	*24.1*		*107.57*
Sucrose + Yeast Pwd. (2-1), Distilled Water			
Laboratory	52.0	25	27.96
Insectary	48.6	9	108.46
Average	*50.3*		*68.21*
Sucrose + *Proteose-peptone* + Yeast (4-1-1), Distilled Water			
Laboratory	46.3	8	63.00
Insectary	39.2	8	277.00
Average	*42.7*		*170.00*

COMPARISON OF LABORATORY AND INSECTARY.—During the past season, experiments carried on in the laboratory rearing cabinet were duplicated in the insectary. The results, in part, are shown in table 4. In general, there was a decided increase in egg production under insectary conditions, the one exception being in experiments with *Proteose-peptone*. This last may be due in part, at least, to the hygroscopic properties of the material which, on exposure to the high humidities prevailing at night, takes up atmospheric moisture and becomes very sticky. Many flies were lost when they became stuck in the food smear. In order to improve its physical character, an equal part of yeast powder was added. The resulting mixture was not only improved in this respect but also increased egg deposition under insectary conditions. Other combinations of proteins and of proteins with urea failed to increase egg production. In addition, it may be noted that the preoviposition period was almost always shorter in the insectary.

The better results obtained in the insectary may possibly be explained as

effects of fluctuating temperature and humidity although this is rendered doubtful by the fact that the second largest egg deposition occurred in the rearing cabinet under constant conditions. Another possibility is that the food smears in the insectary were in a more suitable condition for the growth of beneficial microorganisms on which the flies fed. All smears in the insectary tended to become moist and moldy, while those in the laboratory remained too dry for the growth of microorganisms. Those containing either *Proteose-peptone* or *Bacto-peptone* were exceptions in that they retained a semisolid consistency, though never becoming as soft as in the insectary.

CONCLUSIONS.—On the basis of histological studies of the ovaries (Dean 1935), it is estimated that a female is capable of laying from 200 to 300 eggs, a number obtained in only one experiment, although approached in some others. In addition, there is a considerable variation in the results obtained from replications of an experiment. This suggests that present methods of rearing apple maggot adults are lacking in some factor, or factors, necessary for normal egg production which, at times, may be supplied naturally, and more readily in the insectary than under laboratory conditions. Experimental evidence as to its nature is lacking, but there are indications that it may be the effect of fluctuating temperature and humidity, exposure to high temperatures for short intervals or the presence of microorganisms in the food.—12-17-37.

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The Scurfy Scale and Its Control*

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At the present time the scurfy scale, *Chionaspis furfura* (Fitch), is not an important pest in commercial apple orchards of New York state except in a small area in the Hudson Valley fruit district where it has become exceedingly destructive. During the past three years the writer has had an opportunity to study the pest in this area, which is about seven miles square and is located in the northern part of Dutchess County and the southern part of Columbia County.

SEASONAL HISTORY, DESCRIPTION AND INJURY.—The insect overwinters in the egg stage under the female scales as shown in fig. 1. The eggs are purplish-red in color, and, according to Aull & Dean (1933), average about 40 in number per scale, with variations from 7 to 83. The scale of the female is somewhat irregularly pear shaped, white or grayish-white in color, and about one-eighth inch in length, fig. 1. The scale of the male is much smaller, with the sides nearly parallel. The dorsal surface bears one median and two lateral longitudinal ridges. The sexes tend to be segregated on certain branches as shown in fig. 2. In many instances, however, they are found intermingled. There are commonly, if not always, two broods annually in the Hudson Valley.

The overwintered eggs begin to hatch about May 10 and the hatch is complete by June 5. Females of the first or spring brood begin to lay eggs during the first week in July, and these eggs start to hatch in about 10 to 12 days. It is the scales of the second or summer brood that infest the current season's growth of wood and the fruit. The second brood females lay eggs in late August and September.

* Approved November 16, 1937, by the Director of the New York State Agricultural Experiment Station for publication as Journal Paper 233.

The lower branches of a tree are usually more heavily infested than those in the top. In serious infestations, some trees in the Hudson Valley area have become so heavily populated with the scales that most of the wood takes on a grayish or scurfy appearance as shown in fig. 2. In such cases many of the twigs, larger limbs and even entire trees are killed. Another important type of injury is that caused by the presence of scales on the fruit as illustrated in fig. 3. In addition to the objectionable appearance of the scales themselves, infested fruits bear depressed and reddish colored areas where the scales settle down.

CONTROL EXPERIMENTS.—In 1933 Aull & Dean reported on results of two years of control experiments in which various dilutions of tar wash and lubricating oils were tested. The writer has had an opportunity to continue these studies and to increase the number of formulae tested. Control tests have been conducted against both the egg stage and the young nymphal or "crawler" stage of the scale.

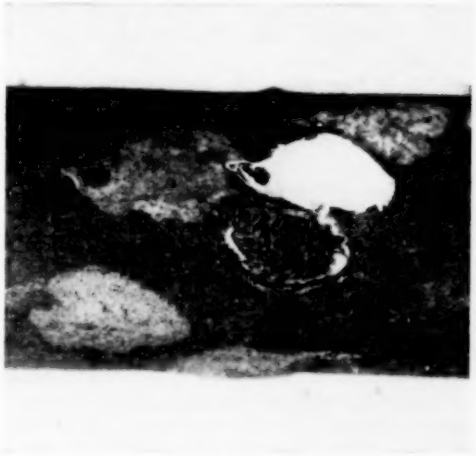

FIG. 1.—Female scales enlarged, with one overturned to show underlying group of eggs.

FIG. 2.—Infested twigs showing male scales on the twig above and female scales on the twig below.

FIG. 3.—Baldwin fruit infested with scales.

OVICIDE TREATMENTS.—The measures applied against the egg stage consisted mainly of dormant applications of emulsions containing various dilutions of (1) coal-tar oils, (2) combinations of coal-tar and lubricating oil, (3) lubricating oil, (4) lubricating oils containing dinitro-o-cyclohexylphenol and (5) lime sulfur solution.

The coal-tar oil used was a commercial emulsion containing 85 per cent actual tar oils. The tar and lubricating oils were mixed as a commercial emulsion contain-

ing 37 per cent coal-tar oils and 46 per cent lubricating oil. The lubricating oil used alone was of a type with a viscosity of about 100 seconds. In 1935 and 1936 the unsulfonatable residue of this oil was about 65 per cent, while in 1937 it was about 75 per cent. This oil was emulsified in the spray tank by using 1 pound of a commercial powdered lignin pitch (Goulac) in each 100 gallons of spray.

The dinitro-o-cyclohexylphenol oils, for the sake of brevity to be referred to in this paper as DN-oils, were of two classes. In 1936 a commercial product of this composition was used: 75 per cent lubricating oil, 3 per cent dinitro-o-cyclohexylphenol and 22 per cent emulsifier. This material will be referred to as DN-oil, Emulsion A. In 1937 the manufacturer supplied the oil in which 4 per cent of the dinitro-o-cyclohexylphenol, by weight, had been dissolved in 96 per cent of oil by weight. This preparation was emulsified in the spray tank by using an emulsifier supplied by the manufacturer. This emulsion will be referred to as DN-oil, Emulsion D.

All of the control tests reported here were conducted on mature apple trees. In 1935 the McIntosh variety was used exclusively, in 1936 the Ben Davis variety and in 1937 the Baldwin variety. Single tree plats were used for each treatment tested. Applications were made when the weather was calm to avoid spray drift from one tree to another. Although varying amounts of spray were used, depending on the size of the trees, an effort was made to obtain complete coverage and yet avoid excessive spray run-off. Sprays were applied by an operator on the ground. Modern equipment which delivered 400 pounds pressure was used.

Unless otherwise indicated, the applications were made during the spring dormant period; that is, the treatments were made during the last few days in March or the first week in April when the weather was mild and before the apple buds had advanced to the "silver tip" stage. This is usually 10 to 14 days before any green tissue appears in this section. The sprays were applied during the warmer part of the day to allow the materials to dry should the temperature drop to freezing. As a result of observing these precautions there was little or no spray injury to the trees.

The technique employed in securing control data was as follows: When hatching of the overwintered eggs was complete, as determined by examination of the eggs on untreated trees, several (25 to 30) infested twigs were collected from various parts of the tree and taken to the laboratory. There the samples were placed under a dissecting microscope and, by means of a pointed instrument, individual scales were turned over and the underlying group of eggs was examined and rated as to whether or not the lot had hatched. Egg masses which had hatched were readily recognized by the presence of light colored and collapsed membranous egg shells, as compared with the dark and shriveled appearance of the dead eggs. Usually, if any of the eggs under the scale were killed by the treatments all were killed. However, in a few instances some were killed and others not. In such cases the mass was recorded as hatched. Approximately 1000 egg masses were examined from each treated and each check tree. Data on the control obtained with some of the more important dormant treatments are presented in tables 1 and 2.

Table 1.—Results of some dormant treatments on the scurfy scale.

Materials	Per Cent Total Oil	Per Cent Egg Masses Killed		
		1935	1936	1937
Coal-tar oil	2.5	65.3	—	—
Coal-tar oil	3.0	89.8	72.8	55.8
Coal-tar oil	3.5	96.8	89.4	65.2
Coal-tar oil	4.0	—	97.4	81.4
Coal-tar oil	4.5	92.8	95.2	93.9
Coal-tar oil	5.0	—	95.2	—
Coal-tar oil	6.0	—	95.7	—
Tar-lubricating oil	3.0	97.0	91.9	91.0
Tar-lubricating oil	3.5	97.4	94.0	91.4
Tar-lubricating oil	4.0	—	97.6	94.3
Tar-lubricating oil	4.5	98.9	98.2	—
Tar-lubricating oil	5.0	—	99.3	—
Tar-lubricating oil	6.0	98.6	99.1	—
Lubricating oil	6.0	90.9	92.3	91.4
Liquid lime sulfur, 1–8		3.4	7.4	16.7
Check		1.1	4.3	3.6

A rather marked decrease in control efficiency occurred with the lower dilutions of coal-tar oil emulsions used in 1937 as compared with previous years. This may be explained partly by the fact that the stock emulsion used in 1937 was held

over from the 1936 supply and had been subjected to freezing temperatures during the intervening winter. However, no faulty characteristic was noted in the emulsion at the time the sprays were applied.

In addition to the tests listed in tables 1 and 2, several other spray mixtures were applied as dormant treatments or after a small amount of growth had taken place. One series consisted of dormant applications of tank-mix emulsions in which the amount of lubricating oil was maintained at 3 per cent and the tar-oil varied as follows: 0.5 per cent, 1.0 per cent, 1.5 per cent, 2 per cent and 2.5 per cent. The data obtained from one season's tests indicate that commercial control may be procured with any of these formulae.

Another series of experiments included the use of *Watkins Insecticide, Dip and Disinfectant*, a proprietary tar acid oil dip. According to the manufacturer, this material contained about 70 per cent tar acid oil, 26 per cent being phenol and 44 per cent other tar hydrocarbons. It is also reported as containing 20 per cent anhydrous soap and 10 per cent water. The stock emulsion used at the rates of 1 gallon, 2 gallons and 3 gallons in 100 gallons of spray gave an efficiency of 27 per cent, 25.7 per cent and 36.8 per cent, respectively.

Applications of a 3 per cent lubricating oil emulsion plus 0.5 per cent cresylic acid and 3 per cent lubricating oil emulsion plus 1 pint of nicotine sulfate in 100 gallons of spray, when applied at the "green-tip" stage, gave 86.4 per cent and 32.0 per cent egg-kill respectively. Sprays applied at the "delayed dormant" stage, containing 3 per cent lubricating oil alone and the same amount of oil plus 1 pint of nicotine sulfate in 100 gallons of spray, gave 90.3 per cent and 95.0 per cent kill, respectively.

Limited tests with fall dormant sprays containing the same dilutions of tar oils as cited in table 1 gave markedly lower efficiencies than the spring dormant sprays.

TREATMENTS FOR THE CRAWLERS.—A satisfactory dormant treatment for the control of the scurfy scale may be selected from some of the several formulae presented here. Because of unfavorable weather conditions or other reasons, however, it is not always possible to apply the dormant treatment. Unless some other means of control is available, a grower may sustain considerable damage to the fruit crop of the current season. An effort has been made to devise some treatment which may be employed during the growing period when dormant sprays have been omitted or have failed.

Table 2.—Results of dormant treatments with lubricating oil containing dinitro-o-cyclohexylphenol.

MATERIALS*	AMOUNT USED PER 100 GALLONS SPRAY		PER CENT EGG MASSES KILLED	
	Gallons Oil	Ounces DN	1936	1937
1% DN-oil, Emulsion D	.96	4.9	—	99.2
2% DN-oil, Emulsion D	1.92	9.8	—	100.0
2% DN-oil, Emulsion A	1.92	9.36	95.8	—
2.5% DN-oil, Emulsion D	2.40	12.2	—	99.0
3% DN-oil, Emulsion D	2.88	14.7	—	98.8
3% DN-oil, Emulsion A	2.88	14.04	98.6	—
4% DN-oil, Emulsion A	3.85	18.73	98.8	—
Check			4.3	3.6

* The emulsions are lettered according to the system used in a paper by Hartzell, Moore & Greenwood, entitled "Control of the Eye-Spotted Budmoth on Apples by Lubricating Oil Containing Dinitro-O-Cyclohexylphenol," which appears in this issue of the JOURNAL OF ECONOMIC ENTOMOLOGY.

Limited tests with summer oil, oil and nicotine, soap and nicotine, powdered derris root, pyrethrum powder and a proprietary mixture of rotenone and pyrethrum extracts gave indications that some of these are toxic to the young nymphal stage of the scurfy scale. In 1937 the most promising of these materials and some additional ones were tested further. The materials were all applied as sprays. Treatments were directed against the second-brood crawlers, which begin to hatch about July 12 to 15. The reason for this was that sulfur is generally used as a

fungicide in early season sprays in this area and this more or less precludes the use of oils for first-brood crawlers on account of the danger of foliage injury resulting from such combinations. The first sprays were applied on July 21 when about 80 per cent of the eggs had hatched. A second application was made on July 27 when the hatch was practically complete. The grower in whose orchard the experiments were conducted applied his last sulfur and arsenical spray about June 20. No injury resulted to the trees from any

either in the stem or calyx end of fruit and constituted practically no commercial loss. 3.—Fruits with 2 to 4 scales. All of the scales on about 60 per cent of these fruits were in the stem and calyx ends, while from 1 to 4 scales were on the sides of the remaining 40 per cent. 4.—Fruits with more than 4 scales per apple. About 90 per cent of these fruits bore 1 to 80 scales on the surface, while the remaining 10 per cent bore all of the scales in the stem and calyx ends.

A summary of the materials used and

Table 3.—Effects of summer treatments on the crawler stage of the scurfy scale.

Materials and Rate Per 100 Gallons*		No. Fruits Examined	Per Cent of Fruits With one scale only	two to four scales	more than four scales	one or more scales	Control Efficiency Per Cent, Based On fruits with more than four scales	fruits infested
Summer Oil Emulsion Nicotine Sulfate	6 quarts 1 pint	1812	5.08	1.10	2.21	8.39	96.11	86.53
Nicotine Oleate Bentonite Fixator	1.5 pints 4 pounds	2269	10.40	9.56	3.0	22.96	94.72	70.25
Summer Oil Emulsion	6 quarts	2318	8.76	8.88	3.91	21.35	93.47	72.34
Nicotine Sulfate Soap Chips	1 pint 3 pounds	1910	10.78	19.39	11.46	36.39	79.85	52.86
Watkins Insecticide Dip and Disinfectant	2 quarts	1816	8.04	25.27	22.25	55.56	60.88	28.02
Watkins Insecticide Dip and Disinfectant	1 quart	1254	5.82	18.98	46.57	71.77	18.12	7.02
Check		2368	4.98	15.33	56.88	77.19		

* The white oil emulsion contained 83 per cent petroleum oil and 17 per cent inert ingredients. Trade name, *Orthol-K* (Medium) California Spray Chemical Company.

The nicotine sulfate contained 40 per cent nicotine. Trade name is *Black Leaf 40*. Tobacco By-Products and Chemical Corporation.

Nicotine oleate, a proprietary product, was designated *NOL30* by the manufacturer. Tobacco By-Products and Chemical Corporation.

The bentonite fixator was furnished under the trade name *Fixator A*. Tobacco By-Products and Chemical Corporation.

The soap chips were sold under the trade name *Clean Quick Soap Flakes*. Proctor and Gamble Company.

Watkins Insecticide, Dip and Disinfectant was a proprietary mixture said to contain 70 per cent tar acid oils (26 per cent phenol and 44 per cent other tar hydrocarbons), 20 per cent anhydrous soap and 10 per cent water. J. R. Watkins Company.

of the subsequent scurfy scale treatments. The same equipment used for dormant spraying was employed for the summer applications.

The efficiencies of the various materials tested were determined by an examination of the windfalls and picked fruit from all of the experimental trees. The fruit was classified into the following four principal categories: 1.—Uninfested fruits. 2.—Fruits with only 1 scale. About 95 per cent of the scales in the second class were

the results obtained by the summer treatments is presented in table 3.

The same materials listed in table 2 were tested on another group of apple trees with a lighter infestation. In this case only one application was made, on July 21. The results obtained were similar to those reported with two applications given in table 3, but further testing is needed to determine the practicability of single treatments.

SUMMARY.—The scurfy scale, although

of no importance in most commercial apple orchards in New York state, is exceedingly destructive in a small area in northern Dutchess and southern Columbia Counties. There are commonly, if not always, two broods of the insect annually in this section. The overwintered eggs hatch over the period from about May 10 to June 5. Eggs laid by the first brood females begin to hatch about July 12 to 15, and the hatch is complete by the last of July. The first-brood scales infest mainly the old wood, whereas many of the second-brood scales infest the new wood and fruit.

The experiments described in this paper indicate that the scurfy scale may be controlled either with dormant treatments or with foliage sprays.

Dormant applications of coal-tar oil emulsions containing 4.5 per cent actual tar oils gave consistently good results over a three-year period. Combinations of tar oil and lubricating oil emulsions containing not less than 3 per cent total oils also proved highly effective, with the toxicity increasing as the total oil content of the spray was increased. A 6 per cent lubricating oil emulsion was about equal to 4.5 per cent tar oil emulsion. All dilutions of lubricating oil emulsions containing dinitro-o-cyclohexylphenol tested gave an efficiency of 95 per cent or better. Liquid lime sulfur used at the rate of 12 gallons in 100 gallons of spray was of little value.

Of the several materials tested as foliage treatments to kill the crawlers, summer oil alone, summer oil and nicotine and a proprietary bentonite nicotine, all materially reduced fruit infestations.—12-17-37.

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Control of Eye-Spotted Budmoth on Apple by Lubricating Oil Containing Dinitro-O-Cyclohexylphenol[1]

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Field tests during 1936 and 1937 have indicated that the budmoth, *Spilonota ocellana* (D. & S.), can be controlled effectively by the use of lubricating oil containing dinitro-o-cyclohexylphenol.[2] The present paper is a summary of results secured with this material in orchards near Geneva during the past two seasons. Dinitro-o-cyclohexylphenol was abbreviated by Kagy & Richardson (1936) to DNOCHP and this usage was followed by Hartzell & Moore (1937). The abbreviation, however, is almost as unwieldy as the full name. Since the manufacturer in factory parlance uses the abbreviation DN for the compound, it seems desirable to substitute this symbol for the name of this chemical compound and the expression DN-oil for solutions of DN in lubricating oil. The term DN-mix will be used for a dry mixture of DN and an emulsifying agent, the use of which will be explained in the next paragraph.

MATERIALS AND MIXTURES.—The manufacturer has furnished DN preparations for the experiment in two distinct combinations: *viz.*, (1) DN-oil, both emulsified and not emulsified at the factory; and (2) DN-mix, a powdered mixture of DN with an emulsifier which can be added to a suitable lubricating oil in the spray tank. Incidentally, it may be stated that DN has a maximum solubility of between 4 and 5 per cent in a lubricating oil having a sulfonation value of 70 per cent. In other words, 100 pounds of DN-oil is usually prepared to contain 96 pounds of oil and 4 pounds of DN. This is the standard for the DN-oil in all the experiments except with emulsions A, B, F and G described in the following paragraphs and shown in table 1.

[1] Approved November 16, 1937, by the Director of the New York State Agricultural Experiment Station for publication as Journal Paper 231.

[2] The compound was prepared by the Dow Chemical Company, Midland, Michigan.

Two lots of DN-oil emulsified at the factory were furnished in 1936. The first is designated Emulsion A and contained in the emulsion, which was of the mayonnaise type, 75 per cent by weight lubricating oil and 3 per cent of DN. Thus the proportion of DN to oil was about 3.8 to 96.2. The second lot, designated Emulsion B, contained in the emulsion 81 per cent by weight lubricating oil and 4 per cent of DN. The emulsifier was a petroleum soap that contained no water. The proportions of DN to oil was about 4.7 to 95.3 and it is presumed that a portion of the DN was dissolved in the emulsifier. Another preparation furnished in 1936 and 1937 was a DN-oil consisting of lubricating oil, 96 per cent, and DN, 4 per cent. This was emulsified in the spray tank during 1936 by means of lignin pitch (Goulac)—Emulsion C—at the rate of 1 pound in 100 gallons of spray mixture. In 1937, an emulsifier supplied by the manufacturer was used at the rate of $1\frac{1}{4}$ pounds in 100 gallons of spray mixture to emulsify the DN-oil in the spray tank—Emulsion D.

The preparations mentioned in the preceding paragraph were all made by dissolving the DN in the oil at the factory. A new product was offered for experimental trials in 1937. This material is designated DN-mix. It is a powder composed of DN, 35 per cent, and an emulsifying agent, 65 per cent. The DN-oil was made in the spray tank by first adding some water, then the lubricating oil and finally the DN-mix in an amount to make a DN-oil containing 96 per cent of oil and 4 per cent of DN. For example, if one desires to make a 3 per cent DN-oil spray in a total of 100 gallons of spray mixture, he should add 2.88 gallons of lubricating oil with sufficient water to allow the agitator to be effective, after which 2 pounds and 9.7 ounces of DN-mix is sifted on the oil. This means that 14.6 ounces of DN is added to the oil. The outfit is started and an emulsion is effected, after which water is added until the 100 gallon mark is reached.

Table 1.—Compositions of emulsions of lubricating oil and dinitro-o-cyclohexylphenol.

Emulsion	Stock Material			Emulsifier Used in Tank Mixing		Proportion of DN to Oil	Remarks
	Per Cent Oil	Per Cent DN	Per Cent Emulsifier	Kind[1]	Pounds Per 100 Gallons		
A	75	3	22	—	—	3.8:96.2	Emulsion made at factory
B	81	4	15	—	—	4.7:95.3	Emulsion made at factory
C	96	4	0	Goulac	1	4:96	
D	96	4	0	Powder[2]	$1\frac{1}{4}$	4:96	
E	100	0	0	Goulac	1	0:100	Lubricating oil No. 2
F	75	3	22	Goulac	$\frac{1}{2}$	1.9:98.1	Emulsion A, 1.92 gals.+ lub. oil No. 2, 1.5 gals.
	100	0	0				
G	75	3	22	Goulac	$\frac{1}{3}$	2.5:97.5	Emulsion A, 2.56 gals.+ lub. oil No. 2, 1 gal.
	100	0	0				
H	0	35	65	—	var.[3]	4:96	DN-mix+lub. oil No. 1
I	0	35	65	—	var.[3]	4:96	DN-mix+lub. oil No. 2

[1] No attempt was made to learn the composition of emulsifiers in DN products nor the one furnished separately by the manufacturer, since these are regarded by the authors as trade secrets.

[2] An emulsifier furnished separately for emulsifying DN-oil in the spray tank.

[3] Amount of emulsifier varied with the amount of oil in 100 gallons of spray mixture.

Of course it is possible with DN-mix to make any proportion of DN to oil within the limits of the solubility of DN in the oil. In order to compare the effect of DN-oils made by means of DN-mix with those prepared in the factory, the proportion (by weight) of oil and DN was kept at 96 to 4 for all concentrations of the former used in the experiments. The few days with conditions suitable for making dormant applications in 1937 excluded proposed tests with varying proportions of oil and DN by the use of DN-mix. It will be noted that several such tests were made during 1936 by adding lubricating oil to DN-oil emulsions, table 1. Two kinds of lubricating oil were used in the experiments. The specifications are as shown in table 2.

All the factory preparations of DN-oil were made with oil no. 1. This oil was also

used with DN-mix except in instances where oil no. 2 was used for comparison. In 1936, oil no. 2 was used for diluting DN-oil to reduce the proportion of DN to oil in several tests.

DESCRIPTION OF EXPERIMENTS.—In central and western New York, budmoth infested orchards usually contain varieties that are susceptible to injury by rosy apple aphid, *Anuraphis roseus* (Baker). In some instances other pests may be present, such as the fruit tree leaf roller *Archips argyrospila* (Walk.), oystershell scale, *Lepidosaphes ulmi* (L.), or San José scale, *Aspidiotus perniciosus* Comst. For this reason, dormant sprays for budmoth are usually designed to control other pests that may be present if susceptible to dormant treatment. Orchards were selected for the tests, if possible, where a number of these species were present in the same area, and also where several varieties were interplanted in order to obtain the greatest amount of data from each treatment.

In the orchards used for budmoth experiments the varieties of apples sprayed were as follows: Orchard A: Rhode Island Greening; Orchard B: Baldwin, Gravenstein, Rhode Island Greening and Rome Beauty; Orchard C: Rhode Island Greening and Rome Beauty; Orchard D: Baldwin, Rhode Island Greening and Wealthy. As regards age and size of the trees, orchard A had moderately large trees about 30 years old; orchard B had very tall, high headed trees over 50 years of age; in orchard C the trees were low headed and about 15 years old; orchard D had moderately large trees about 25 years of age. The data for 1936 were secured from orchards A and B; orchards C and D supplied the data for 1937, all of which are given in table 3.

Table 2.—Specifications of two kinds of lubricating oils used in the experiments.

PROPERTIES	OIL NO. 1	OIL NO. 2
Specific Gravity	0.905	0.88
Viscosity at 100° F. (Saybolt)	111 seconds	100 seconds
Pour Point	−21° F.	25° F.
Sulfonation Value	72	75

Table 3.—Effects of treatments on budmoth during 1936 and 1937.

PER CENT DN-OIL IN SPRAY MIXTURE	EMULSION	MATERIAL IN 100 GALLONS OF SPRAY MIXTURE		NO. OF TREES	PERCENTAGE EFFICIENCY	
		Oil Gals.	DN Ozs.		Weighted Average	Weighted Average of Similar Treatments
1½	A	1.44	7.0	4	81.9	
1½	B	1.43	8.6	2	90.9	
1½	C	1.44	7.4	4	81.9	83.7
2	A	1.92	9.4	8	93.4	
2	B	1.91	11.5	8	95.1	
2	C	1.92	9.8	8	96.2	
2	D	1.92	9.8	4	85.8	
2	H	1.92	9.8	4	92.0	93.4
2½	D	2.40	12.2	4	95.8	95.8
3	A	2.88	14.0	17	98.1	
3	B	2.86	17.1	8	97.7	
3	C	2.88	14.7	8	96.6	
3	D	2.88	14.7	4	89.6	
3	H	2.88	14.7	11	94.7	
3	I	2.88	14.7	4	95.6	96.2
4	D	3.84	19.5	6	92.6	
4	H	3.84	19.5	12	98.4	
4	I	3.84	19.5	5	94.3	96.0
	E	3	0	13	21.4	21.4
3	F	2.94	7.0	8	88.5	88.5
3	G	2.92	9.2	10	95.6	95.6

Rosy apple aphid was moderately abundant in 1936 and was very scarce during 1937. Orchards A and B were moderately infested with San José scale with about 45 per cent of the overwintering scale alive when examined early in March, 1936, but a severe ice storm a few weeks later reduced the number of living scales to about 8 per cent. Orchard D, in addition to having the most serious infestation of budmoth encountered in eight years of experimentation, was also very heavily infested with oystershell scale.

All the spraying was done with a modern, motorized spray-rig at a pressure of 400 pounds, two leads of hose being used with the regular single outlet type of spray-gun on each. All spraying was done with the operators on the ground and each tree was completed in one operation. The spraying simulated that used by the best commercial practice both in thoroughness and rapidity of treatment. The aim was to determine whether DN-oils and many other kinds of spray mixtures can be relied upon to give commercial control if the treatment is as thorough as can be accomplished by apple growers without using excess material and at the same time maintain a speed sufficient to cover a reasonable acreage.

Many of the treatments were replicated either in the same planting or in other orchards, and in very few cases, due to missing trees, were there less than four trees per plat. Great care was exercised to avoid the drifting of spray on either check trees or plats treated with another mixture; in fact it was necessary in some instances to rearrange the plats at the time of spraying to avoid this undesired effect.

METHOD OF SECURING AND ANALYZING DATA.—During late June and early July the cocoons of the budmoth are readily found. Since they are full grown caterpillars and pupae that hibernated as small larvae, they are a reliable index of the number of larvae present at the time the dormant treatments were made. Moreover, the caterpillars do not migrate from tree to tree. Counts of the cocoons on each tree selected for data were made on the lower branches to a height of about 10 feet. From the average number of cocoons on the trees of the same variety on a treated plat, and similar data from check trees of the same variety, a percentage efficiency of the treatment was calculated by the usual method. Although the actual number of cocoons on check trees in the same orchard usually varies greatly according to the variety of apple, and although the number on check trees of the same variety in different orchards fluctuates considerably, the percentage efficiencies for the same mixture are rather constant on different varieties and in separate orchards. The same holds true for the same mixture in different years. Owing to the number of mixtures used, the number of orchards, varieties and the two seasons involved, space does not permit a detailed presentation of the data. Because of the uniformity of the percentages of efficiency for the same mixture under these various conditions, it is believed that no serious error is committed by taking averages of percentages of efficiency for plats treated with the same mixture. The weighted average is considered more nearly accurate; therefore the percentage efficiency of each plat has been weighted by the number of trees in the same plat. The results with each treatment are set forth in the column headed "Weighted Treatment Average" in table 3. In order to compare mixtures having considerable differences in amounts of oil or DN, a weighted average of similar treatments has been computed in the same manner as just described for treatment averages. These are found in the last column of table 3.

CONCLUSIONS.—The following conclusions, concerning the control of budmoth, seem warranted from the data:

1.—DN-oil at 3 per cent concentration, and containing lubricating oil and DN in the ratio of approximately 96 to 4, is very effective in the control of the budmoth under conditions found in western New York orchards.

2.—The efficiency increases, in general, with the dosage to and including 3 per cent DN-oil mixtures.

3.—No gain in efficiency seems to be secured by increasing the dosage above 3 per cent of DN-oil.

4.—In general, diluted spray emulsions of the same DN-oil content gave similar results regardless of the manner of preparation or kind of emulsion used.

5.—With practically the same lubricating oil content, the effectiveness increased in proportion to the DN in the

mixture. At the same time, mixtures having approximately the same DN content apparently show some increase in effectiveness with an increase of lubricating oil.

6.—The two brands of lubricating oil at the same concentration and DN content gave similar results.

7.—Lubricating oil at 3 per cent concentration without DN was not sufficiently toxic to give commercial control of budmoth.—12-17-37.

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Sparganothis sulfureana Clem., A Cranberry Pest in New Jersey*

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Sparganothis sulfureana Clem. is commonly known as false yellowhead, or sulfur leaf roller. It is an omnivorous feeder that has been reported on the following food plants: apple, celery, corn, cranberry, red and white clover, pitch and white pine, honey locust, strawberry, willow, great burdock, tall buttercup, blue and white vervain and horseweed.

The collection of this species in the United States National Museum contains specimens from Florida, Mississippi, Colorado, Utah and Washington. It has been recorded commonly in most of the states northeast of these commonwealths. Forbes (1884) describes this species as follows:

> This insect may be described in general terms as a brownish yellow moth, the fore wings of which are marked by two V-shaped brown bands (the apex of the angle pointing backwards), so placed that when the wings are closed these markings form an X.
>
> The palpi are long, nearly or quite twice the length of the head, yellow above, deep red laterally and beneath. The antennae are reddish brown; the head and thorax are yellow above, tinged with red or purple at the sides; the patagia red in front, yellow beyond. Anterior wings, golden yellow, finely reticulated with red or purplish (sometimes the reticulations are wanting), costa tinged with purple at base. A purple spot on the middle of the internal margin throws out two diverging lines, one of which attains the costa at the basal third, the other ending just below a similarly colored subapical costal spot. The internal margins more or less tinged with purple somewhat constant, and deepest towards the base; fringes yellow. Posterior wings above and beneath varying from pale yellowish fuscous to dark fuscous or blackish. Under surface of anterior wings clouded centrally with fuscous; the margins paler, sometimes yellow. Abdomen brownish, legs pale silvery brown, anterior ones darkest. Expanse, male, 14 to 17 mm.; female, 17 to 19 mm.

The original description of this insect was published in 1860 (Clemens), and since that time notes have been published occasionally calling attention to its work on various plants. Often a life cycle was suggested that would agree with the isolated observations made during the year. Infestations of economic importance have been reported on celery in Michigan (Davis 1893), on cranberries in Wisconsin (Hardenburg 1908) and on cranberries in Massachusetts (Franklin 1907). No one has previously reported the actual rearing of this insect to determine its seasonal history.

DAMAGE.—Damage to cranberries is caused by this insect in three ways: by destroying the fruit buds in spring, by webbing and eating the foliage and by mining the fruit. Franklin (1907) indicated that, under the conditions observed, the destruction of the fruit buds was the most serious type of damage. In New Jersey, during 1935 and 1936, all three types of damage were important, but the mining of the fruit was the most obvious. Each second brood larva would mine from three to five berries, and it is estimated that two-thirds of the crop on two bogs was destroyed in this manner.

SEASONAL HISTORY.—The dates reported here are taken from the records of

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several series of individual specimens reared in an outdoor insectary at Pemberton, N. J. These records were checked against field observations and corroborated by them. Unless otherwise stated, the dates reported refer to insectary observations.

Adults emerging in September, 1936, laid eggs within two days. They were deposited in masses up to 60, usually between 30 and 50. In the lantern jar cages, the eggs were laid on the glass and, in the field, on the upper side of the cranberry leaf. A mass of 52 eggs was 6 mm. long and 2½ mm. wide and one layer of eggs thick. On the dark green of the leaf, the eggs appeared colorless but on glass they had a definite yellow tint.

The eggs hatched in from 9 to 12 days. The newly hatched larva had a shining black head and was 1 to 2 mm. long. It made a small tentlike web shelter on the under side of the leaf or on the stem. In 1936, the larvae under study ate very little during the fall and winter and did not grow at all. As the terminal buds started to swell toward the end of April (April 24, 1937), the larvae left their tents and started to feed on these buds. Ordinarily, the larvae ate the green part of the bud, leaving the brown shell, as observed previously by Franklin (1907). As new growth started, the larvae attacked this, webbing two leaves together, and later extended their tubelike web to include more leaves, all of which were skeletonized so severely that they turned brown. The larger larvae have a light yellow head. The full grown larvae are 10 to 15 mm. long.

Larvae reached maturity irregularly, the first pupae being observed on May 30 and the last for this brood on June 20. The pupal stage lasted from 7 to 12 days and occurred in the web where the larvae had been feeding. The first adults emerged June 6 and the last the first week in July. Adults were common on the infested cranberry bogs during the latter half of June and the first week in July.

The first eggs of the next brood appeared on June 21 and they were common during the first half of July. After an incubation period of from 9 to 12 days, the larvae appeared and started to feed on the foliage and in some instances on the bloom. The larvae preferred the fruit, however, and attacked it almost exclusively after the berries were half grown. A single larva would destroy three to five berries, eating the center out of each and, on maturing, would pupate inside the last berry. Pupation started August 2, but there was an occasional larva of this generation as late as September 27. Most of the pupae appeared the last week in August and early in September.

Eggs were found in the cages on August 11 and some were found in November. The greatest number appeared between September 6 and 26. The incubation period again was from 9 to 12 days, and the young larvae webbed up as they did the year previously.

A small percentage of the winter brood of larvae fed and grew during September, especially those in the earlier hatch. None reached the pupal stage. Possibly these individuals do not survive the winter, as no such forms were found in the spring of 1937 among the several hundred examined in the cages. No adults appeared on the bogs before the large emergence about June 25.

The year's cycle is briefly summarized in table 1.

Table 1.—Seasonal cycle of *Sparganothis sulfureana*.

	Form	Average Starting of Stage
Winter Brood	Larvae	Over winter
	Pupae	June 10 to 15
	Adults	June 20 to July 4
Summer Brood	Eggs	June 21 to July 5
	Larvae	July 1 to 15
	Pupae	Aug. 25 to Sept. 15
	Adults	Sept. 5 to 25
Winter Brood	Eggs	Sept. 6 to 26
	Larvae	Sept. 15

CONTROL.—Submergence, the usually effective insect control measure on cranberry bogs, is of little avail in fighting *S. sulfureana* Clem. The finding of large larvae feeding on cranberry foliage on June 1, 1937, indicated that the young larvae endure the ordinary cranberry bog winter submergence of 5½ months (November 25 to May 15). One lot was submerged experimentally on March 10 and the water removed May 2 without noticeable mortality. The flooding delayed the earlier feeding but the average larva matured as early as those from unsubmerged

vines. Larvae, nearly mature, were submerged for 48 hours (June 7 to 9) and were not killed by the treatment. Many of the larvae in the treated material floated away but those that stayed on the vines matured after they had dried.

Cage tests carried on in the apparatus of Doehlert (1936) indicated that the adults could be killed by an application of 30 pounds of pyrethrum dust (.9 per cent pyrethrins) to the acre but, on account of the irregularity of emergence, this treatment was not considered practical under ordinary conditions. An airplane application of 15 pounds of derris dust (4 per cent rotenone) to the acre was not effective in killing larvae in a single field experiment (June 2, 1937).

Spraying with arsenate of lead, two pounds to 50 gallons of water, was an effective control measure. The poison was added to the Bordeaux-soap spray being made on June 3 and 4. It was applied at the rate of 200 gallons to the acre on thin vines and 300 gallons on heavy vines. There was very little fruit damage found in the area where the first brood was so treated. It was not 100 per cent effective, however, as some moths were noted during September and early October, but occasional misses are common in spraying. It was the most satisfactory method that was tried.

PARASITES.—Parasites present in the material collected in early September, 1936, were identified by the staff of the United States National Museum as follows: *Nemorilla floralis* Fall. (Det., D. G. Hall); *Anachaetopsis tortricis* Cog. (Det., D. G. Hall); *Meteorus trachynotus* Vier. (Det., C. F. W. Muesebeck); *Microbracon mellitor* Say. (Det., C. F. W. Muesebeck); *M. gelechiae* Ashm. (Det., C. F. W. Muesebeck); *Sympiesis ancylae* Gir. (Det., C. F. W. Muesebeck); *Oncophanes atriceps* Ash. (Det., C. F. W. Muesebeck); *Angitia paenerivalis* Vier. (Det., R. A. Cushman).

DISCUSSION.—Failure to note *S. sulfureana* before in New Jersey indicates that serious attacks occurred infrequently and minor injury passed unnoticed or was charged to other pests. One old grower is reported to have said, "When yellow-headed fireworm (*Peronea minuta* Rob.) eats little foliage in June, it destroys plenty of berries in August." This describes fairly well the work of *S. sulfureana*, and the report may be taken as evidence that the insect occurred, although it was not recognized as a distinct species.

Cranberry growers have been using a quick method to determine three of their common insect pests. Ordinary leaf webbers were either black-headed fireworm (*Rhopobota vaciniana* Pack.) or yellow-headed fireworm and were easily distinguished by the color of the larval head. There was only one fruitworm, *Mineola vaccinii* (Riley), and a larva inside the fruit needed no further identification. *S. sulfureana* is black-headed at one time and yellow-headed at another; the second brood feeds in the fruit. The addition of this pest to the list of common insects interferes greatly with the quick and easy identification of all three of the well known pests.

In general, *S. sulfureana* browns the leaves less than is normal for the first brood of either of the common fireworms. and the web is smaller, rarely including more than one upright. The larvae in the fruit can be identified, roughly, by the appearance of the mine; usually the ordinary fruitworm partly fills the hole with dark brown frass, while the hole left by the present species is clean. Pupation inside of the berry is typical of *S. sulfureana* and is very unusual with the common fruitworm.

There is no evidence that this insect will become a general pest, since it has already been noted as being temporarily serious in two widely separated places, and then for twenty years there was no mention of it. In a more recent publication (Franklin 1928) it was noted as being common in some bogs but never plentiful enough to do much harm. With the additional knowledge of the two very serious attacks in New Jersey in 1935 and 1936, the conclusion may be reached that the insect is capable of doing great harm when conditions are right.

Probably the most peculiar feature of this insect's seasonal history is its endurance of winter submergence. There is no record of other leaf feeding larvae withstanding such treatment, although it has been known with soil infesting grubs and lepidopterous larvae in cocoons in the soil. It is also unusual for full grown larvae to withstand a 48-hour submergence.—12-17-37.

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Southern Corn Shipments and Their Relation to Corn Ear Worm Infestations on Long Island*

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Three explanations have been offered to account for the sources of early summer infestations of the corn ear worm, *Heliothis obsoleta* (F.), in the latitude of Long Island although very little actual evidence seems to have been presented:

1. The actual overwintering of at least a small number of pupae on Long Island, particularly during the milder winters.

2. The northward migration of moths each season from southern sources.

3. The presence of moths which have developed from corn ear worm larvae occurring in Southern shipments of green corn received in Northern markets, particularly New York City, during a period prior to the local green corn season (Britton 1930).

In the Southern states, the corn ear worm hibernates during the winter months as a pupa in the ground, although not without a considerable amount of mortality. Phillips & Barber (1929) reported that during a study conducted in Virginia over a period of years, approximately 95 per cent of the larvae entering the soil in the fall failed to emerge as moths the following season. A comparable situation was reported after further observations in Virginia by Barber & Dicke (1937), although these writers report a higher rate of survival in other tests conducted at Savannah, Ga., probably because of more favorable hibernation temperatures. It appears that on Long Island the conditions favoring pupal survival are less propitious than in states farther south because of more severe winter temperatures. Hibernation tests conducted on Long Island during the winters of 1934, 1935 and 1936, employing a technique similar to that used in the Virginia tests of Phillips & Barber (1929), revealed an almost complete overwintering mortality. Similar negative results have been reported orally to the writer by other workers who have conducted tests in the general latitude of New York City.

The present paper is concerned principally with a report of an examination of 10 lots of Southern corn purchased in the wholesale market district of New York City during 1936 and 1937. An attempt is made to evaluate, in a preliminary way, the importance of Southern corn shipments as a source of Long Island corn ear worm infestations. Preliminary mention is made of a hibernation survey conducted on Long Island during the spring of 1937, although a detailed discussion of the corn ear worm hibernation situation on Long Island will be deferred until further observations have been completed.

METHOD OF STUDY.—Information concerning corn ear worm occurrence in Southern corn was obtained by purchasing bushel samples at random from commission merchants at the Washington Street wholesale produce market in New York City. Each sample was examined to determine the extent of corn ear worm infestations and injury, the proportion of ears containing live corn ear worm larvae and the numbers of live larvae sufficiently mature to become potential sources of local corn ear worm infestations in the event that the corn were taken to some favorable outlying area where pupation in the soil would be possible. Four samples were obtained during June and July,

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1936, and six samples were obtained during May, June and July, 1937. All of the larger live corn ear worm larvae which were found were removed from the ears and, in most cases, were successfully reared to moths.

ANALYSIS OF SOUTHERN CORN SAMPLES.—The information obtained from an examination of 552 ears comprising 10 bushels of Southern corn is summarized in table 1. From these data it will be noticed that a very high proportion of the ears showed corn ear worm injury and that a much smaller proportion contained

would appear possible that, over a period of years, some relationship might be found between the quantity of corn imported into the general area and the extent of early corn ear worm infestations. If, on the other hand, it is assumed that Long Island corn ear worm infestations are due primarily to pupae which have passed the winter locally in the soil it appears that some relationship might be found between the severity of winter temperatures and the extent of early corn ear worm infestations. In table 2 is summarized the available information concerning these

Table 1.—Occurrence of corn ear worm larvae and larval injury in Southern corn purchased in New York City wholesale vegetable markets.

DATE PURCHASED	SOURCE	NUMBER OF EARS	PER CENT EARS WITH WORM INJURY	PER CENT EARS WITH LIVE WORMS	PER CENT EARS WITH MATURE LIVING WORMS	PER CENT EARS COMMERCIALLY CLEAN
1936						
June 2	Texas	52	96.1	36.5	17.3	34.6
3	Florida	48	95.8	18.8	8.3	20.8
16	Louisiana	60	100.0	36.7	25.0	3.3
July 7	Carolina	48	89.6	45.8	29.2	22.9
1937						
May 27	Texas	53	98.1	41.5	0.0	22.6
June 3	Texas	50	92.0	22.0	10.0	66.0
10	Texas	48	91.5	12.8	2.1	38.3
17	Florida	66	74.2	19.7	9.1	45.5
24	Florida	60	73.3	16.7	3.3	41.7
July 1	New Jersey*	67	79.1	46.3	22.4	25.4

* The sample from Edgewater Park, N. J., purchased July 1, 1937, cannot be strictly considered as Southern corn. It is included as a sample of corn from approximately the northernmost source available at the time of purchase.

living worms. A still smaller proportion of the ears contained worms which could be considered as approaching maturity. It was observed that some worms were crushed during shipment and that others were lost from the containers during handling at the markets. A number of worms were found which appeared to have died from disease and from conditions associated with refrigeration during shipment. When the ears were graded for injury by the same standards used in corn ear worm control experiments on Long Island it was found that a relatively low, though variable, proportion could be considered "commercially clean," or free from injury below the silk channel at the tip of the cob.

SOUTHERN CORN AND LONG ISLAND CONDITIONS.—If it is assumed that Long Island corn ear worm infestations are due principally to the importation of live worms in green corn from other areas it

factors during the four-year period from 1934 to 1937. The data concerning corn ear worm infestations were obtained by the writer from infestation counts made in Nassau County, N. Y., which adjoins the eastern boundary of New York City. Each count ordinarily involved the examination of not less than 50 ears of corn in various stages between silking and harvest. Infestation records for the latter part of the season are not shown since, regardless of early conditions, high ear worm populations developed during the last month of each corn growing season.

From table 2 it will be noticed that fluctuations occurred in Southern corn shipments as well as in local conditions on Long Island during the four-year period shown. The decrease in Southern corn shipments in 1937 is believed due to unfavorable growing conditions in the Southern states. The July corn ear worm infestations on Long Island appear to

fluctuate with preceding winter conditions, the higher infestations following the less severe winters. From table 2 it appears that local winter conditions may have a greater influence on Long Island corn ear worm incidence than the amount of Southern corn available in New York wholesale markets. This would indicate the possibility of a local reservoir of infestation in the annual survival of at least a small number of pupae during the winter months.

PUPAL SURVIVAL ON LONG ISLAND.—After three seasons of almost completely negative results from hibernation tests in which cages of the type described by Phillips & Barber (1929) were used, another method of study was attempted in the spring of 1937.

It was realized that if an overwintering mortality of 95 per cent occurs in Virginia, as reported by Phillips & Barber, an even greater mortality could be expected in the colder latitude of Long Island. It was also realized that, because of the known high fecundity of the female moths, a very small number of individuals could produce at least a light corn ear worm infestation each year during July. An attempt was made to examine soil under field conditions for the presence of corn ear worm pupae. During May and early June, 1937, 10 plots 10 feet square were chosen at random in a three-acre field near Roslyn, Long Island, in which sweet corn had been grown during the latter part of the 1936 season and in which a heavy infestation of corn ear worms had been observed. The soil in each plot was removed to a depth of one foot and carefully examined for pupae. In the 1000 cubic feet of soil examined, six live pupae were found which, upon rearing, produced moths of the corn ear worm. This indicated a survival at the rate of over 250 pupae per acre.

Further work of this sort is planned before a complete report can be made, although this single series of observations indicates that the corn ear worm pupa is capable of surviving a mild winter on Long Island. It appears possible that similar observations on a more extensive basis may indicate a slight amount of pupal survival even after severe winters.

Table 2.—A comparison of Southern* corn receipts at New York City with winter conditions and corn ear worm infestations on western Long Island.

YEAR	CARLOADS† OF SOUTHERN CORN RECEIVED AT N. Y.§	LONG ISLAND JULY CORN EAR WORM INFESTATIONS			NATURE OF PRECEDING WINTER ON LONG ISLAND
		Average Per Cent of Ears Infested	Per Cent Range of Infestations	Number of Records	
1934	358	9.7	0.0–38.0	24	Severe
1935	363	23.3	0.0–74.0	14	Average
1936	303	6.3	0.0–27.0	17	Severe
1937	177	22.0	0.0–58.7	28	Mild

* For the purposes of this table the term "Southern" is restricted to denote only the coastal states from Texas to North Carolina, inclusive.

† Shipments arriving by all agencies (rail, boat, truck) are expressed in terms of carloads.

§ The data concerning Southern Corn shipments were obtained from reports distributed by the Market News Service of the New York Office of the Bureau of Agricultural Economics, United States Department of Agriculture.

CONCLUSIONS.—It has been established that live corn ear worm larvae are regularly brought into the New York area from states to the south. For a period of from four to six weeks before the first local sweet corn becomes available these larvae, infesting Southern green corn, are distributed through various produce outlets within the city and in the principal outlying communities. Exact figures are difficult to obtain, although it appears that the greater proportion of larvae infesting such Southern green corn are probably destroyed during the course of transportation, retailing and garbage disposal. Under favorable conditions it has been possible for corn ear worm moths to develop from such larvae although, under actual conditions, it may be questioned whether any significant proportion of the moths responsible for the early infestations of the corn ear worm on Long Island originates from this source.

No relationship appeared to exist in the data available between the volume of Southern green corn received at New York and the extent of the early corn ear worm infestations on Long Island during the same season. Observations indicated

however, that the heavier early infestations were preceded by relatively mild local winter conditions and that the lighter early infestations were preceded by relatively severe winter conditions.

Preliminary observations have established that the corn ear worm can survive mild winters on Long Island, although further work is needed to determine the extent of survival after severe winter conditions. It is believed that little improvement in the Long Island corn ear worm situation would result from the erection of restrictions against Southern corn brought to New York markets.—12-17-37.

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Results of Potato Dusting Experiments on Organic Soils

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During the past five years, 1933 to 1937, inclusive, spraying and dusting experiments were conducted on organic soils in western New York in order to determine the most efficient procedure under muckland conditions. Most of the experiments were conducted with the Irish Cobbler potato since this is the variety commonly grown on muckland, although some experiments were also conducted with the Smooth Rural variety.

The luxuriant growth of potato vines grown on organic soils provides an excellent environment for potato insects. The most numerous insect pests of muckland potatoes are the following: potato leafhopper, *Empoasca fabae* (Harr.); Colorado potato beetle, *Leptinotarsa decemlineata* (Say); potato flea beetle, *Epitrix cucumeris* Harr.; and aphids, mainly *Myzus persicae* (Sulz.), involved in the spread of virus diseases.

Early blight lesions were usually moderately abundant, but late blight did not occur in the regions where the experiments have been conducted.

EXPERIMENTAL PROCEDURE.—Commercial fields of potatoes varying from 3 to 10 acres in extent were used in all the experiments. When the fields were too small to allow at least four replications in each treatment, the experiment was conducted on adjoining fields separated by a willow windbreak. This practice increased the soil heterogeneity and thereby increased the yield variation, although the results obtained in this manner present a more practical picture to the potato growers. Due to the large acreage involved, all treatments were applied by means of modern power machinery. The spray was applied with a horse-drawn power sprayer carrying a six-row boom with three nozzles to each row. The Bordeaux mixture, 4-2-50 concentration, was applied at 350 pounds pressure and at an average rate of 110 gallons to the acre at each application. The dusts were applied at the rate of 35 to 40 pounds of dust to the acre in each application by means of a six-row traction duster.

Dust or spray applications were started when the larvae of the Colorado potato beetle began to cause injury to the potato vines. In the western New York muckland area the first treatments were usually applied either late in June or the first week of July. The number of applications varied from year to year, depending on insect abundance and the growth of the potato vines.

The efficiency of the treatments was determined by estimation of the injuries on the vines or by actual insect counts and finally by weighing the yields of tubers obtained from the different plots in the field at harvest time. Since tuber yields are of the greatest practical importance, the effect of the various treatments on the resultant yields was summarized[1] for the present paper. All comparisons were made with "untreated" plots that actually received one treatment of calcium arsenate at the time of the

Table 1.—Comparative yields in bushels per acre of dusted and sprayed Cobblers grown on muckland.

TREATMENTS	1933 5 APPLICATIONS		1934 4 APPLICATIONS		1935 3 APPLICATIONS	
	Yield	Gain	Yield	Gain	Yield	Gain
Untreated	105		306		250	
Copper-Lime Dust, 20:80	165	60	298	−8	251	1
Bordeaux Spray, 4-2-50	164	59	305	−1	254	4
Significant Differences*						
With Odds of 21:1		21.8		20.7		22.0

* Differences between any two means equal to twice the standard error of mean differences were considered to be significant. The standard error was obtained by the analysis of variance method.

first application when all treatments contained calcium arsenate to control the Colorado potato beetle.

COMPARISON OF DUSTING AND SPRAYING.—Initially, most of the experiments were spraying experiments, since the spray could be applied at any time during the day. Variations in formulae and in concentrations of spray could also be readily changed, and spray could be applied with a minimum of drift. However, over a period of three years, no marked differences in yields were obtained between the dusted and sprayed potato vines, table 1, although the spray gave a better control of insect pests. These results were obtained when the copper-lime dust was applied on calm mornings on plants wet with dew, and equivalent amounts of copper were applied as Bordeaux on sprayed plots during the same day.

Another highly significant point is that yield increases of copper sprayed or dusted plants over the untreated were obtained in 1933 only. In 1933, the potato leafhopper was a serious pest and yield differences were attributed to the control of this insect. In 1934 and 1935, the leafhopper populations varied greatly from field to field. In some fields they caused damage while in other fields the leafhopper did not appear in large enough numbers to result in yield gains from the application of insecticides which controlled the insects.

The yield figures given in this paper, tables 1 through 4, are net yields; that is, they include the mechanical injury of the spraying and dusting operations. This mechanical injury is greater in spraying than in dusting because of the excessive weight of the water and sprayer. Since dust applications require a less expensive machine and can be applied more rapidly than the spray, and since they result in less wheel injury to the vines, most growers prefer to dust. On muckland, however, conditions for applying copper-lime dust are not always ideal; that is, there are many mornings when the dew is insufficient to form a Bordeaux on the foliage. To overcome this difficulty, a variety of dust materials has been tried.

COMPARISON OF DUST MATERIALS.—The most promising materials that can be applied to dry potato foliage were found to be dusts containing sulfur. Ordinary dusting sulfur, 325 mesh, applied to dry foliage has given consistently better yields than copper-lime dust applied to wet foliage on the same day, table 2. These better yields were obtained in dry seasons, 1934 and 1936, when it was most profitable to dust and in wet seasons, 1935 and 1937, when the treatments were not highly profitable. Statistically significant gains in yields of the sulfur dusted plots

Table 2.—Comparative yields in bushels per acre of dusted muckland Cobbler potatoes over a four-year period.

DUST TREATMENTS	1934 4 APPLICATIONS		1935 3 APPLICATIONS		1936 3 APPLICATIONS		1937 4 APPLICATIONS	
	Yield	Gain	Yield	Gain	Yield	Gain	Yield	Gain
Untreated	287		298		174		432	
Copper-Lime, 20:80	318	31	287	−11	191	17	430	−2
Sulfur, 325 Mesh	333	46	297	−1	210	36	459	27
Significant Differences								
With Odds of 21:1		39.5		19.2		14.2		55.0

over the untreated were obtained in 1934 and 1936, but significant differences in yields between copper and sulfur dusted plots were obtained in 1936 only. Over the four-year period the differences in yield between the copper-lime and sulfur dusts are statistically significant although the lumping of yearly results may be questioned.

In general, sulfur dusted plots had fewer potato leafhoppers and tarnished plant bugs but more flea beetles than the copper-lime dusted plots. All the treated plots had fewer insect pests than the untreated, except late in the growing season when the treated plots had more potato aphids than the untreated. However, some of the differences in yields between sulfur and copper-lime dusted plants may be due to differences in physiological responses of the plant to the dust treatments.

EFFECT OF CONTACT INSECTICIDES.—Adding contact insecticides, such as nicotine and pyrethrins, to the sulfur dust usually gave additional increases in yield over the sulfur alone. The addition of the insecticides to the sulfur greatly increased the cost, and it is questionable if the increases in yields, which were not statistically significant, justified the increase in cost. The results summarized in table 3 were obtained in a dry season. In a wet year the order of effectiveness of the materials would probably be changed.

COMPARISON OF POTATO VARIETIES.—In addition to the experimental work reported above, there has been some work conducted with different potato varieties. Limited experiments indicate no differences in response of various potato varieties to dust or spray treatments except those due to variability in time of maturity. Late potato varieties on muckland usually receive the greatest amount of insect injury because the insects move from the early varieties, which die off, to the late varieties, which are still green.

Table 3.—Average yields in bushels per acre of muckland Cobblers receiving four dust applications in 1934.

DUST TREATMENTS	AVERAGE YIELD	GAIN OVER UNTREATED	GAIN OVER SULFUR
Untreated	287		
Bentonite+¾% Nicotine	316	29	
Copper-Lime, 20:80	318	31	
Sulfur, 325 Mesh	333	46	
Sulfur+0.05% Pyrethrins	341	54	8
Sulfur+¾% Nicotine	343	56	10
Sulfur-Bentonite, *Kolodust*	348	61	15
Sulfur+0.10% Pyrethrins	354	67	21
Significant Differences With Odds of 21:1		39.4	37.4

The Smooth Rural potato is the only late variety that has been grown to any great extent on muckland in western New York. Therefore, only those results obtained with this one late variety are presented in table 4. As was expected, slightly larger gains in yields were obtained from treatments applied to the late variety than from those applied to the earlier Irish Cobbler.

The dilution of copper-lime dust with equal amounts of sulfur dust gave excellent results in 1937. It will be noted that plants treated with this copper-lime-sulfur dust gave the largest tuber yields in both the Cobbler and Smooth Rural potato varieties. Although the increased yields of the copper-lime-sulfur dusted plots over the untreated plots are not quite statistically significant in either variety test, these gains become highly

Table 4.—Comparative yields in bushels per acre of two potato varieties on muckland receiving four insecticide treatments during the season.

TREATMENTS	1934 RESULTS				1937 RESULTS			
	Cobbler		Smooth Rural		Cobbler		Smooth Rural	
	Yield	Gain	Yield	Gain	Yield	Gain	Yield	Gain
Untreated	306		207		432		425	
Copper-Lime Dust	298	−8	220	13	430	−2	448	23
Copper Spray	305	−1	237	30	not used		not used	
Sulfur Dust	not used		not used		456	24	460	35
Copper-Lime-Sulfur Dust	not used		not used		475	43	468	43
Significant Differences With Odds of 21:1		20.7		23.7		55.0		46.6

significant if the results are combined irrespective of the variety. Since copper is the specific remedy for late blight it might be highly profitable to retain a large share of copper in sulfur dusts. Further experiments on the most profitable formula to use under diverse climatic and soil conditions will be necessary before any recommendations can be made.

SUMMARY.—Field experiments in dusting and spraying Irish Cobbler and Smooth Rural potatoes grown on organic soils in western New York have been conducted during the past five successive seasons, 1933 to 1937, inclusive. Although Bordeaux spray gave a better control of insect pests than copper-lime dust, no marked differences in yields were obtained between dusted and sprayed potatoes.

Sulfur dusts applied to dry foliage gave consistent, but usually not statistically significant, increases in tuber yields over copper dusted potato plants. Further increases in yields which were not statistically significant, were obtained by adding pyrethrins or nicotine to the sulfur dusts. A copper-lime-sulfur dust has given the largest tuber yields in 1937 with both varieties of potatoes used in the experiments. This promising dust combination warrants further study in the control of potato insects and diseases.

A large part of the tuber yield increases obtained with the dust and spray treatments on muckland potatoes could be attributed to the control of the potato leafhopper. Some of the differences in yield obtained may also be due to differences in the physiological response of the potato plant to the different treatments. —12-17-37.

The Carrot Weevil, *Listronotus latiusculus* (Boh.), A New Pest on Celery[1]

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On June 11, 1936, W. Raymond Stone, County Agricultural Agent of Bergen County, N. J., delivered to the senior author several celery plants which were badly damaged by what appeared to be larvae of some kind. The insects had deserted the plants. Records of such damage could not be found in the Entomology Department files. Field collections of specimens were made and the insect was found to be *Listronotus latiusculus* (Boh.).[2] A review of the literature revealed no record of this insect as a pest of celery. The writers had the opportunity to devote some time during 1936 and 1937 to a study of this pest.

HISTORICAL.—The carrot weevil was described from Pennsylvania by Boheman in 1842. Since the insect was first taken from the arrow weed plant, *Sagittaria variabilis*, it received the name sagittaria curculio. Then in 1902 the same insect was reported as injurious on parsley in Virginia. Since the eggs were laid in the stalks and the young larvae fed chiefly on the stalks and crown, it was given the common name of parsley stalk weevil. The same insect was later reported as a pest on carrots and is now referred to as the carrot weevil. Shropshire & Compton (1935) list *L. latiusculus* and *L. rudipennis* as carrot weevils. Chandler (1926) speaks of *L. latiusculus* as the carrot weevil. Then Harris (1926) gives an account of a new carrot pest, *L. rudipennis*.

According to Blatchley & Leng (1916) all species belonging to the genus *Listronotus*, as far as the habits and life histories are known, breed in semiaquatic plants. Buchanan (1932) is of the opinion that Weed's original specimens reared from sagittaria are *Hyperodes solutus* instead of *L. latiusculus*. If this is the case, it is possible that the so-called semiaquatic plant feeding species of *Listronotus*, as mentioned by earlier workers, belong to the genus *Hyperodes*. *L. latiusculus* certainly does not appear to breed in semiaquatic plants in New Jersey. After heavy rains, dead larvae were found in celery hearts, which leads the authors to believe that they are easily drowned.

This insect has been reported as a pest

[1] Paper of the Journal Series, New Jersey Agricultural Experiment Station, Department of Entomology.
[2] Determined by Carl Ilg and John B. Schmitt.

on parsley from Virginia, Connecticut, the District of Columbia and New York; also, as a pest on carrots from Illinois, Iowa, New York, the District of Columbia, and it is now known as a carrot pest in New Jersey.

County agents and vegetable growers have often mentioned the injury to carrots by the carrot rust fly in sections where the carrot weevil is found abundantly. For the past two seasons the writers have visited a large number of carrot fields, but no signs of carrot rust fly were present, while severe damage by *L. latiusculus* was common. The growers said that this damage was what they had called rust fly work. It is the opinion of the writers that this pest has been working on carrots for a number of years but that it has been confused with another insect.

DISTRIBUTION IN THE UNITED STATES.—Blatchley & Leng (1916) give the distribution of the weevil as follows, "The type is from Penn. Ranges from Quebec, New England and Michigan, west and south to Colorado, Kansas and Georgia." Smith (1910) reports this species as occurring throughout New Jersey. Other states in which the insect has been reported as a pest are listed above under "Historical."

DISTRIBUTION ON CELERY IN NEW JERSEY.—*L. latiusculus* was found attacking celery only on muck soil in Bergen County, just north of Hackensack. Celery is the main crop grown on the muck soil in northern New Jersey. These muck areas are found in Warren, Sussex, Morris, Passaic and Bergen Counties. Celery plantings have been examined in all five of these counties, and damage by *L. latiusculus* was found only in the plantings near Hackensack, Bergen County. Celery on upland soils has been examined over a two-year period without any signs of weevil injury, although nearby carrot plantings were found to be severely injured. From small plantings of carrots beside celery fields on the muck soil, the indications are that the beetle did not show preference between the two plants. From observations on the habits and seasonal history of the species on the muck soil, it is somewhat of a mystery why the weevil does not attack celery on upland soils adjoining the infested muck area, as well as other areas where it is present on carrot and wild carrot.

FOOD PLANTS.—In reviewing the history of *L. latiusculus*, the authors found no mention of celery, *Apium graveolens* L., as a food plant. A list of food plants is given above in the history of the insect. The writers made a survey of the food plants of the carrot weevil during the summer of 1937. It was reasonable to assume that since the beetle was found on celery only in the muck area in Bergen County and since this was the first record of its attack on celery it had evidently transferred to a new food plant.

All plants growing in the vicinity of the celery fields were examined for injury and the presence of grubs. Any plants harboring weevil grubs of any kind were brought to the laboratory and the grubs reared to adults. *L. latiusculus* was reared from the following plants: celery (*Apium graveolens* L.), cultivated and wild carrots (*Daucus carota* L.), broad leaf plantain (*Plantago major* L.), patience dock (*Rumex patientia* L.), parsley (*Petroselinum hortence* Hoffm.), and dill (*Anethum graveolens* L.). Adult beetles were also found on all of the above plants at some time during the season. It is interesting to note that *L. latiusculus* was reared from patience dock and broad leaf plantain from the Bergen County area only. These specimens were collected in May, 1937. Later collections of these two species of plants in Bergen County and other points throughout the state produced *Hyperodes sparsus* only.

L. latiusculus was reared from carrot and wild carrot from Atlantic, Cumberland, Gloucester, Burlington, Mercer, Somerset, Middlesex, Monmouth, Essex, Morris, Passaic, Warren, Sussex and Bergen Counties.

Large numbers of arrowhead plants (*Sagittaria variabilis*) which grow along the drainage ditches in the celery fields were carefully dissected and no signs of grubs or their injury were present in these plants. This is contrary to the findings of Weed (1889) and others. Our survey, however, does not prove that *L. latiusculus* never attacks the arrowhead plant.

INJURY AND LOSSES.—*L. latiusculus* may injure celery at any stage of growth from the time the plants are placed in the field until the crop is harvested. Injury has not been observed in the seedlings grown in the greenhouse. When the weevil attacks young plants, the larvae

eat out the heart, and the plants eventually die. When larger plants are attacked, oftentimes they are dwarfed and seldom recover. The stalks of large plants are tunneled, and the celery is unfit for market, fig. 1. The degree of injury depends to some extent on the planting date. It was not uncommon to find fields

FIG. 1.—A large celery plant showing the injury of *Listronotus latiusculus* larvae.

in which 50 per cent of the young plants had been killed. Injury in fields of celery which were ready for market often ran as high as 35 per cent. The adult weevil damages the plants by feeding in the groove of the larger stalks, rendering the plants unsalable or making them seconds.

Chandler (1926) and Boyce (1927) give accounts of the injury on carrots. Chittenden (1924) gives a description of the injury on parsley.

LIFE HISTORY AND HABITS.—Boyce (1927) gives the most nearly complete account of the life history of *L. latiusculus* on Long Island, N. Y., yet he reports only a one-year study of the insect. The writers have merely touched upon the life history of the species, but found that there were three generations in New Jersey in 1937. On May 12, adult beetles were found on young celery plants and eggs were present at that time. Twenty-three egg punctures were examined on May 13 and, in these, 31 eggs were found. The eggs hatched in 9 to 17 days in May, while in the second brood the time was reduced to from 7 to 13 days.

Larvae were found in the field on May 20. Cage-reared larvae reached maturity in an average time of 14 days. The larvae may feed in any portion of the celery, stalks or large roots, but the usual feeding place is in the growing heart. The tunnels made by the larvae often reach 12 to 14 inches when the eggs are deposited in the uppermost part of the stalk. The larvae may bore through several stalks near the base of the plant.

When the larvae reach maturity they crawl out of the plant and build an earthen cell near the exit hole and there pupate. First generation pupae require about 11 days before emerging as adults. The pupal stage may be completed in 6 days during the second and third generations. The life history in New Jersey is comparable to that on Long Island as reported by Boyce (1927).

The adult weevils pass the winter in grass and debris around and in the celery fields. Many of the celery farms have sod along the banks of the drainage ditches to prevent caving of the banks, and it has been found that the sod makes ideal hibernating quarters. Beetles were collected from under boards, in the field, stacks of bleaching boards, old pieces of bleaching paper, leaves in nearby woods, etc.

The first beetles were collected in hibernation cages on May 2, 1937, while the last beetle was collected on May 30.

As reported by Boyce (1927) and others, the adults are sluggish and invariably feign death when disturbed. There is no record in the literature of beetles having been observed in flight; however, the senior writer has observed them on the wing. Four specimens which flew in the windows of a moving automobile were captured. Two adults were captured while in flight. From the above observations they seem to be poor fliers.

Table 1.—The effects of insecticidal treatments against the carrot weevil on large celery, first brood.

PLOT NO.	TREATMENT	PLANTS EXAMINED	NO. INJURED	PER CENT INJURED
1	Commercial apple plus sodium fluosilicate bait	200	27	13.5
2	Poison bran bait (cutworm formula)	200	40	20.0
3	Calcium arsenate, 3 lbs.; lime, 6 lbs.; skim milk, 1 lb. to 100 gals. water	100	10	10.0
4	Calcium arsenate, 25 lbs.; lime, 73 lbs.; skim milk, 2 lbs. (dust)	200	21	10.5
5	Check—no treatment	200	49	24.5

Although the beetles fly, it is doubtful whether they migrate very far. On one celery farm in the Hackensack area on which no sod is to be found, on which the ditch banks are kept free of vegetation and all crop remnants are turned under as soon as the crops are harvested, a very low percentage of the celery crop is injured by *L. latiusculus*. This seems to indicate that the elimination of hibernating quarters decreases the infestation the following year.

CONTROL.—The only control measure suggested in the literature is crop rotation. This practice is impossible under New Jersey conditions because the available celery land is limited.

During 1936 insecticide experiments were undertaken and several organic insecticides were tested, namely, derris root as a dust, derris root as a spray, pyrethrum dust, phenothiazene both as a spray and as a dust, and fixed nicotine as a spray and as a dust. The only material which showed any promise was phenothiazene-talc dust (20–80).

In 1937 further testing of insecticides was undertaken. Five plots of approximately one-tenth acre were laid out on one farm and four of these plots were replicated on an adjoining farm. At the time the first application of insecticides was made approximately 5 per cent of the plants showed egg punctures or injury by small larvae. The baits were applied at the rate of 40 pounds per acre per application; the dust at the rate of 30 pounds per acre; and the spray at the rate of 100 gallons per acre. Each plot received four applications at 10-day intervals. The results obtained are set forth in table 1.

Since 5 per cent of the plants were injured before the treatments were started it seemed that the apple plus sodium fluosilicate bait, calcium arsenate plus lime dust and the calcium arsenate spray offered possibilities as a control. In order to get further information on these materials a series of plots was set up on second brood. The materials tested and the results obtained are set forth in table 2. These plots were one-tenth of an acre

Table 2.—The effects of insecticidal treatments against the parsley stalk weevil on small celery, second brood.

PLOT NO.	TREATMENT	NO. PLANTS COUNTED	NO. PLANTS DEAD	PER CENT PLANTS DEAD	NO. PLANTS EXAMINED FOR INJURY	NO. PLANTS INJURED	PER CENT INJURED	PER CENT DEAD OR INJURED
1	Check A	1000	143	14.3	400	59	16.8	21.1
2	Commercial apple plus sodium fluosilicate bait	500	24	4.8	200	2	1.0	5.8
3	Home made apple bait, 90 lbs. dried apples, 10 lbs. Paris green	500	20	4.0	200	4	2.0	6.0
4	Home made raisin bait, 40 lbs. raisins, 40 lbs. bran, 10 lbs. Paris green	500	38	7.6	200	9	4.5	12.1
5	Phenothiazene-talc dust (1–9)	500	29	5.8	200	5	2.5	8.3
6	Calcium arsenate plus lime dust (1–3)	500	34	6.8	200	5	2.5	9.3
7	Check B*	1000	234	23.4	400	69	17.5	40.9

* This check was in an adjoining field which was set 10 days later than the test plots.

in size. The treatments were started on July 16, three days after the celery plants were set in the field. Applications were made July 16 and 26, August 5 and 18. The amount of material used per application was the same as that applied on first brood.

The weather was very unfavorable during the second brood experiments, and heavy rains occurred immediately after two of the four applications. Samples of celery were taken out of the arsenical plots and analyzed for arsenical residue, which was found to be below the legal tolerance.

This work will be continued in the future until a control is worked out for the pest on celery.—12-17-37.

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Recent Problems on Long Island in the Control of Bean Insects[1]

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Bush beans of snap and lima varieties are grown extensively on Long Island. The former type is raised largely in the western area as succession plantings or catch crops; the latter is particularly suitable for conditions as they exist in the eastern sections. The chief pests of the foliage and fruit are the Mexican bean beetle, *Epilachna varivestis* Muls.; common red spider, *Tetranychus telarius* (L.); potato leafhopper, *Empoasca fabae* (Harr.); bacterial spot, *Bacterium vignae* Gard. & Kend.; and downy mildew, *Phytophthora phaseoli* Thaxt. In the experiments under review, the Mexican bean beetle was prevalent throughout the season, leafhoppers were numerous for a short period during August, common red spider and bacterial spot were not noticeable and mildew was absent.

Cubé powder has been generally accepted as the safest material with which to combat the Mexican bean beetle, and copper-lime mixtures as the surest protection against bacterial spot and mildew. With the prevalence of injury by common red spider during recent seasons, there has been considerable interest shown in the use of sulfur dusts. The application of this material as an insecticide is viewed with a certain degree of hesitancy by the average grower owing to certain unfortunate experiences in the past relative to its use as a soil corrective to inhibit the growth of the potato scab organism.

The following experiments were carried out with a view to obtaining data concerning certain points in procedure in the use of insecticides and fungicides about which there appeared to be little satisfactory information. The points at issue may be briefly enumerated as follows: 1.—What value has a cubé powder that according to analysis is low in rotenone content but considered satisfactory in total extractives? 2.—What effect, if any, have applications of sulfur dusts on soil reaction as denoted by pH? 3.—Is it possible to use cubé powder effectively on

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foliage treated with copper-lime mixtures?

TESTS ON SNAP BEANS.—Experiments concerning the comparative insecticidal value of cubé powder of low rotenone but of satisfactory total extractive content and concerning the possible effect of sulfur applications on soil acidity were carried out as part of two series of experiments dealing with the culture of snap beans. Two samples of cubé powder (*Lonchocarpus nicou*) were compared, one analyzing 2 per cent rotenone and 18 per cent total ether extractives and the other 5 per cent rotenone and 12 to 14 per cent total ether extractives.[2] These powders were applied in sulfur spray and dust mixtures at strengths equivalent to 4 pounds of cubé powder to 100 gallons of wettable sulfur spray and 10 pounds of cubé powder in 100 pounds of a cubé plus *Celite* plus ground sulfur dust mixture.

The tests were carried out in two series during the period of infestation by the first and second generations of *E. varivestis* Muls. In the first series, the plots comprised the rows of three succession plantings and were replicated nine times in row units of 20-foot length. Five applications of spray were made at approximately eight-day intervals, commencing June 14. Mixtures were applied along the sides of rows by means of hand machines at an average rate of 126 gallons of spray per acre per application and 30 pounds of dust mixture. The cumulative effect of such applications was estimated according to the number of larvae and resultant pupae of *E. varivestis* found on the first planting of beans two to three days after treatment, and according to yield from each of three succession plantings. Pods were picked at weekly intervals commencing June 26, June 30 and July 17 in the three respective plantings.

In the second series of tests, plots were replicated four times in systematic series. Three applications were made, on July 6 to 8, July 16 and July 27, respectively, at rates comparable to those in the first series. Results were recorded in terms of yield from weekly pickings made from July 21 to August 3. Summarized data from these experiments are presented in tables 1 and 2.

Table 1.—Tests of cubé powder of contrasting analytical content combined with sulfur mixtures applied to bean foliage, and their effect on larval population of *Epilachna varivestis*.

FORMULAE (Parts by Weight)	NUMBER OF PLANTS	NUMBER OF LARVAE AND PUPAE COUNTED ON			
		June 25	July 2	July 10	July 19
Cubé powder (5:13),* 4; wettable sulfur, 20; water, 800	194	192	95	4	164
Cubé powder (5:13), 10; *Celite*, 2; ground sulfur, 88	186	293	353	123	165
Checks	195	1967	2690	3879	3039
Cubé powder (2:18),† 4; wettable sulfur, 20; water, 800	208	387	388	65	54
Cubé powder (2:18), 10; *Celite*, 2; ground sulfur, 88	212	373	325	43	80
Checks	201	1443	2314	2600	3847

* 5 per cent rotenone and 12 to 14 per cent total ether extractives.
† 2 per cent rotenone and 18 per cent total ether extractives.

RESULTS OF TESTS ON SNAP BEANS.—Through the data given in tables 1 and 2 it may be seen that differences between treatments with mixtures containing cubé powders of contrasting analytical content were relatively small. In both cases counts showed a marked drop in larval population of treated rows at the beginning of the period of treatment. During the course of following applications, the numbers after each rarely exceeded those at the first count, whereas in checks the population invariably showed notable increases from week to week. According to yield of pods, there is little to indicate that differences in analytical content of the stock powders had much influence in shaping the results. The average gains over the respective checks indicated that such differences in rows sprayed and in those dusted were insignificant.

[2] Supplied through the courtesy of S. B. Penick and Company.

Table 2.—Yield of snap beans from plants treated with sulfur mixtures containing cubé powder of contrasting analytical content during infestation by *Epilachna varivestis*.

FORMULAE (Parts by Weight)	YIELD IN GRAMS PER 100 PLANTS SERIES 1				SERIES 2	
	Planting 1	Planting 2	Planting 3	Average Gain	Planting 1	Average Gain
Cubé powder (5:13), 4; wettable sulfur, 20; water 800	8589	7288	5028	1093	3422	936
Cubé powder (5:13), 10; *Celite*, 2; ground sulfur, 88	8122	7076	5775	1115.7	3512	1026
Checks	7925	5401	4300			
Cubé powder (2:18), 4; wettable sulfur, 20; water 800	5691	5695	4584	776.3	3313	827
Cubé powder (2:18), 10; *Celite*, 2; ground sulfur, 88	6626	5852	4342	1059.7	3819	1333
Checks	5797	4575	3269		2486	

These results would indicate that cubé powders in which total extractives attained the higher brackets and rotenone content was low may be used effectively at commonly recommended dosage in spray and dust mixtures to prevent injury by the Mexican bean beetle.

With respect to the effect of sulfur applications on soil reaction as indicated by the pH, the readings in all instances furnished negative results, table 3. Only summarized data pertaining to rows dusted with sulfur are presented, since it is in this practice that greatest apprehension exists concerning the ultimate deleterious effect on following crops. As indicated by Wessels (1932) the possible cumulative effect of small amounts of sulfur applied annually to the soil over a short period of years may under certain conditions have serious effects locally on the aftercropping unless appropriate measures are taken to rectify the situation. The inclusion of a crop dusted with sulfur in a rotation with other crops not thus treated seems to be the simplest and safest way out of any danger that may lie in such a measure.

TESTS ON LIMA BEANS.—With growers of lima beans the problem of controlling the Mexican bean beetle is complicated by the fact that Bordeaux mixture and copper-lime dust are in general use as fungicides to combat infection by downy mildew and bacterial spot. These mixtures, on account of their alkaline reaction, are considered incompatible to use with cubé or pyrethrum powder.

In tests with apple aphid and blunt-nosed leafhopper, Doehlert (1935) reported satisfactory kills under laboratory conditions with a Bordeaux-penetrol mixture containing pyrethrum extract. In preliminary field experiments in 1936 on Long Island, Bordeaux mixture proved a valuable asset in measures employed for the control of bean pests, including the Mexican bean beetle.

Further tests were made in 1937 in which Bordeaux mixture, copper-lime dust and sulfur formed the bases of treatments. Cubé powder, analyzing 5 per cent rotenone and 12 to 14 per cent total ether extractives, and pyrethrum powder, of .9 per cent pyrethrin strength, were used as insecticides. In the case of rows sprayed with Bordeaux mixture, insecticide powders were added separately to the tank in

Table 3.—Summarized data relative to the effect of one season's applications of sulfur dusts on soil acidity.

NUMBER OF APPLICATIONS	AVERAGE RATE PER ACRE PER APPLICATION	NUMBER OF SOIL SAMPLES PER TREATMENT	RANGE OF SOIL REACTION (pH) Treatment 1	Treatment 2
6	31 lbs.	30	4.85–5.02	4.80–4.97
5	30 lbs.	30	4.80–5.04	4.59–4.77
4	35 lbs.	30	4.80–4.90	4.75–4.87
3	35 lbs.	30	4.77–4.83	4.65–4.83
Checks		36	4.80–4.97	4.70–4.97

paste form at the time of application, or were separately applied in a *Celite*-clay dust mixture at a favorable opportunity following the application of spray; in the case of sulfur mixtures the powders were applied in combination with sulfur, and in case of rows dusted with copper-lime as separate applications in a *Celite*-clay dust mixture. Formulae for these mixtures are given in table 4.

The plots were arranged in a systematic series of row units, each 20 feet in length.

Table 4.—Effectiveness of spray and dust mixtures containing fungicides and insecticides for control of foliage parasites on lima beans.

Treatment (Parts by Weight)	Percentage Plant Injury Due to *E. varivestis*			Average Weight in Grams Per 100 Plants	
	Slight	Moderate	Severe	Vines	Pods
Bordeaux mixture, 4:6:400*	88	12	0	10625½	4986
Cubé powder,† 4; Bordeaux mixture, 800	99	1	0	9525	5646
Pyrethrum powder,‡ 8; Bordeaux mixture, 800	96½	3½	0	10262½	5690
Bordeaux mixture Cubé powder, 10; *Celite*-clay, 90	96	4	0	9270	5143
Bordeaux mixture Pyrethrum powder, 55; *Celite*-clay, 45	93½	6½	0	10681	4809½
Checks	5½	28	66½	6589½	2054½
Cubé powder, 4; wettable sulfur, 20; water, 800	86½	13½	0	8939	5050
Pyrethrum powder, 8; wettable sulfur, 20; water, 800	34½	42½	23	6851½	4970½
Cubé powder, 10; *Celite*-sulfur, 90	68	26	6	8247	6304
Pyrethrum powder, 55; *Celite*-sulfur, 45	27½	38	34½	7531½	4705½
Checks	6½	25½	68	7382	2195½
Copper-lime dust, 15–85	18	50	32	7659	4205½
Copper-lime dust Cubé powder, 10; *Celite*-clay, 90	23½	56	20½	7229	4376½
Copper-lime dust Pyrethrum powder, 55; *Celite*-clay, 45	14	50½	35½	8109	4506
Checks	5	31	64	6445	2033½

* Including 2 pounds of skim milk powder per 100 gallons.
† Strength of 5 per cent rotenone and 12 to 14 per cent total ether extractives.
‡ Strength of .9 per cent pyrethrins.

Each plot was replicated three times, and treatments were applied by hand machines. Applications of spray were made at average intervals of 13 days, commencing July 17 and ending September 3, at the average rate of 150 gallons per acre per application; dust applications were made at average intervals of 11.5 days, commencing July 19 and ending September 4 at an average rate of 37 pounds per acre per application for copper-lime dusts and *Celite*-clay mixtures and 45 pounds for *Celite*-sulfur mixtures. During this period, infestation by *E. varivestis* was continuous, consisting largely of the progeny of second and third generation adults, and during early August there was a brief but intense migration of adult leafhoppers from adjoining potato fields. There were three pickings of beans, on August 24, September 7 and September 17, respectively. At the close of the season it was clearly apparent that the foliage of plants in rows sprayed with Bordeaux mixture was distinctly superior to that in most of the rows sprayed or dusted with other mixtures, a condition which was not reflected to a comparable degree in the yield of pods from the various rows. It was decided therefore to make an appraisal of the comparative extent of foliage injury by *E. varivestis* and to weigh the vines in addition to weighing the pods in an attempt to evaluate more closely the comparative effectiveness of different treatments. These data are presented in table 4.

RESULTS OF TESTS ON LIMA BEANS.—It will be seen according to the data presented in table 4 that, on all counts, rows sprayed with Bordeaux mixture averaged superior plants when compared with those treated with copper-lime dust or even sulfur. Bordeaux mixture in itself, as applied, appeared to exert considerable influence in checking the extent of feeding

by *E. varivestis*. The addition of cubé or pyrethrum powder to Bordeaux mixture at the time of spraying seemed to impart some added value to the application, the results from which were fully commensurate with those obtained where separate applications of fungicide and insecticide were made. In contrast the results from the use of copper-lime dusts with and without the addition of separate applications of insecticidal dusts were inferior. The results obtained with sulfur dusts and sprays were considerably improved when combined with cubé powder as compared with pyrethrum powder. This was particularly evident in respect to the diminished extent of foliage injury by *E. varivestis*.

These results would indicate that Bordeaux mixture may be used to advantage as a protection against foliage parasites of lima bean, including the Mexican bean beetle. The same cannot be said of copper-lime dusts, the presence of which evidently was partly the cause for the non-effectiveness of cubé and pyrethrum dusts. On the other hand there was little to indicate that cubé and pyrethrum powders and dust mixtures could not be used effectively in conjunction with applications of Bordeaux mixture.

SUMMARY.—Field tests were made comparing the effectiveness of cubé powders of 2 per cent rotenone and 18 per cent total ether extractives and 5 per cent rotenone and 12 to 14 per cent total ether extractives in spray and dust mixtures for control of foliage parasites of beans on Long Island. The powders were used in combination with sulfur sprays at the rate of 4 pounds per 100 gallons, and in dust mixtures at 10 pounds in 100 pounds of complete mixture. According to larval population counts of *E. varivestis* and yield of pods, mixtures containing cubé powder of 2 per cent rotenone and 18 per cent total ether extractives were as effective at the dosages used as those containing cubé powder of 5 per cent rotenone and 12 to 14 per cent total ether extractives. One season's applications of sulfur dusts did not affect the soil acidity as measured by the pH.

In field tests on lima beans sprayed and dusted with copper-lime mixtures for control of plant diseases it was observed that Bordeaux mixture, as applied, possessed considerable merit in that it had notably reduced the amount of feeding by *E. varivestis*. This effect, it was observed, was slightly enhanced by the addition of cubé powder to the mixture at the time of application or by making separate applications of cubé-clay dusts following treatment with Bordeaux mixture.—12-17-37.

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Sorption of Hydrocyanic Acid by Different Species of Insects

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It is a well known fact that some species of insects are much easier to kill with hydrocyanic acid than are others; one insect may require many times the dosage or a much longer period of exposure than another. To cite an extreme case: approximately 0.5 mg. per liter of hydrocyanic acid will kill 99 per cent of the confused flour beetles, *Tribolium confusum* Duv., in a 10-minute exposure period in a nearly complete vacuum whereas about 270 mg. per liter are required to kill 99 per cent of rice weevils, *Sitophilus oryzae* (L.), in the same length of exposure—a difference in dosage of over 500 times. This difference may be due to the fact that the fatal dose for rice weevils is much greater or that confused flour beetles can take up approximately as much hydrocyanic acid from a low concentration as rice weevils

can from a high concentration. A knowledge of the sorption of hydrocyanic acid by the insects is required to determine which factor is more important in killing the insect. A study of the quantities of hydrocyanic acid sorbed by different types of insects was therefore undertaken since to the best of our knowledge no such experiments had been performed.

THE SORPTION APPARATUS.—A diagrammatic sketch of the apparatus[1] used for these sorption determinations is shown in fig. 1. *A* is the sorption chamber where the insects are placed. This is fitted with a ground glass joint so that it may be removed readily from the remainder of the apparatus when necessary. The chamber is maintained at the desired temperature (within $\pm 0.1°$ C.) by means of a beaker of water equipped with coils through which water is pumped from a thermostat. The gas burette, *C*, is also kept at constant temperature by circulating water from the thermostat through a larger tube which surrounds the burette. The volume of the remainder of the apparatus has been reduced wherever possible by means of capillary tubing so that any error introduced into the measurements by changes in room temperature is negligibly small.

B is a vacuum manometer which registers the absolute pressure within the system in millimeters of mercury. Steel rulers are fixed in position between the two tubes of the vacuum manometer and along the open-end manometer, *D* and *E*, so that the levels of the mercury can be read. Magnifying glasses equipped with cross-hairs at the focal points are used to obtain the final readings in both cases. These glasses are fastened to small adjustable clamps which can be raised or lowered at will on vertical rods. In this way the position of the mercury in the tubes can be determined with a precision of ± 0.1 millimeter. The height of the mercury in the gas burette, *C*, is easily and accurately controlled by means of a leveling bulb equipped with a screw adjustment.

The volume of the apparatus has been carefully determined by means of a separate gas burette which is not shown in the diagram. During an experiment the mercury level changes in the gas burette, *C*, in the tube, *D*, and in the vacuum manometer. These changes are read in millimeters on the steel rulers. In order to calculate the corresponding volume changes, the volume of each tube is determined in terms of the millimeter rise or fall of mercury. The readings in millimeters are then easily converted into volumes by multiplying the number of millimeters by the volume equivalent to a one millimeter change. In this way the volume of the apparatus to the right of S_6 (S_3 and S_5 being closed) is known for any position of the mercury in the three tubes. The volume of the sorption chamber (S_6 to S_7) also has been determined. A correction is made for the space occupied by the insects by finding the density of each species used.

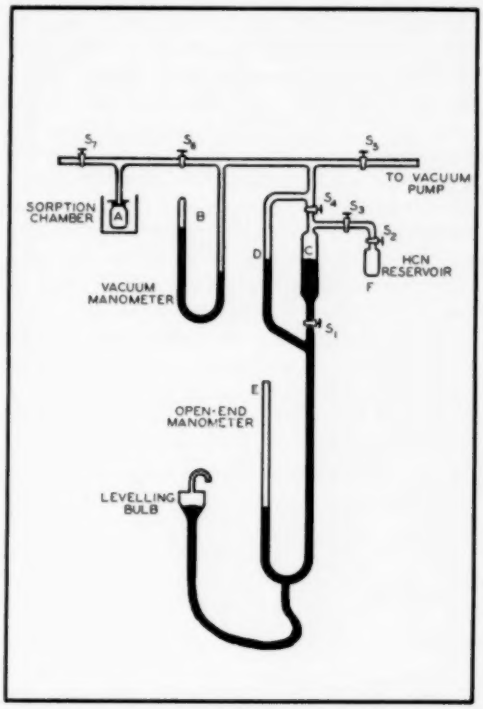

FIG. 1.—Diagram of the sorption apparatus.

Approximately 10 cc. of liquid hydrocyanic acid is placed over calcium chloride in the reservoir, *F*. All the air in the reservoir is then removed by several evacuations at liquid air temperatures. When the stopcocks, S_2 and S_3, are opened during an experiment, the vapor of hydrocyanic acid diffuses into the apparatus. The

[1] The apparatus used was a modification of one designed by Dr. V. Migrdichian of the Stamford Laboratories, American Cyanamid Company, for the study of the sorption of hydrocyanic acid by various commodities and insects.

pressure may then be measured on the manometer.

THE EXPERIMENTAL PROCEDURE.—At the start of an experiment the stopcocks, S_2, S_3, S_5 and S_7, are closed. A weighed quantity of insects is placed in the sorption chamber, S_5 is opened and all of the air removed by evacuation. S_4 and S_5 are then closed and the vapor pressure of the insects, P_1, is read on the vacuum manometer after the pressure becomes approximately constant.[2] S_6 is then closed and the space to the right (to S_2) is completely evacuated. The mercury in the gas burette is now brought to some convenient level on the scale, and S_1 is closed. A predetermined pressure of hydrocyanic acid vapor, P_2, is next admitted by opening S_2. This pressure is read on the vacuum manometer after closed S_2 and S_3 and bringing the level of the mercury in tube D back to the original setting. The sorption of hydrocyanic acid by the insects is now ready to be determined for different time intervals at a chosen constant pressure of hydrocyanic acid, p. When S_6 is opened, since P_2 is greater than P_1, a quantity of hydrocyanic acid vapor passes over into the sorption chamber, thus equalizing the pressure throughout the apparatus. This pressure, P_0, may be calculated by the equation

$$P_0 = P_1 + (P_2 - P_1)\left(\frac{V_2}{V_1 + V_2}\right) \qquad (1)$$

where V_1 is the volume of the sorption chamber from S_6 to S_7, and V_2 is the volume of the remainder of the apparatus to the level of the mercury in the gas burette, C. Immediately after S_6 is opened in the determination, S_1 is opened and the mercury level in the gas burette is so adjusted that the pressure reading on the vacuum manometer is equal to p, the constant pressure of hydrocyanic acid at which the sorption is to be measured. As the insects sorb hydrocyanic acid, this pressure tends to fall off, and consequently it is necessary to raise the level of mercury in C in order to keep it constant. Thus, there is a continual flow of hydrocyanic acid, the rate of which depends upon the rate of sorption of hydrocyanic acid by the insects, from the gas burette to the sorption chamber, at the constant pressure, p. Readings of the level of mercury in the chamber, C, are taken at definite intervals of time while the sorption is taking place. From these readings the quantity of hydrocyanic acid sorbed at any time, t, may be calculated from the equation

q in milligrams

$$= .001478(P_0 - p)V_0 + p\Delta V \qquad (2)$$

where the factor, .001478, is the weight in milligrams of one cubic centimeter of hydrocyanic acid at a pressure of one millimeter at 20 degrees C.; V_0 is the volume of the entire apparatus from S_7 to the level of mercury in the gas burette at the start of the sorption, and ΔV is the change in volume in the gas burette plus the tube, D, from zero time to the time t.

It is best in actual practice so to select P_2, the initial hydrocyanic acid pressure, that P_0 and p have nearly the same value. Only a small adjustment of the mercury in C is then necessary to change from P_0 to p at the start of the sorption, and the term $(P_0 - p)V_0$ in equation (2) is small so that readings of ΔV may be taken soon after the sorption has started. P_2 is therefore calculated before the experiment is started; since we wish P_0 and p to be as nearly equal as possible, p is substituted for P_0 in equation (1). Solving for P_2 we have

$$P_2 = (p - P_1)\left(\frac{V_1 + V_2}{V_2}\right) + P_1 \qquad (3)$$

or, denoting by P^* the value of the partial pressure of hydrocyanic acid over the insects, then

$$p = P^* + P_1 \qquad (4)$$

and

$$P_2 = P^*\left(\frac{V_1 + V_2}{V_2}\right) + P_1. \qquad (5)$$

EXPERIMENTAL RESULTS.—Measurements have thus been made for the sorption of hydrocyanic acid by rice weevils, *S. oryzae* (L.); confused flour beetles, *Tribolium confusum* Duv.; German cockroaches, *Blatella germanica* (L.); yellow mealworms, *Tenebrio molitor* L.; and cigarette beetles, *Lasioderma serri-*

[2] This is due primarily to water evolved by the insects and is approximately equal to the vapor pressure of water at the temperature of the experiment. The pressure very slowly increases above that of the water vapor due to the evolution of carbon dioxide. This causes a small error in sorption measurements, which is not appreciable unless a large number of insects is used, as in the case of the rice weevil. A small correction has been made in the measurements of sorption by rice weevil, based on gas evolved by the insects during the run.

Table 1.—Quantities of hydrocyanic acid sorbed by several species of insects. (Partial pressure of HCN = 47.5 mm.; T = 20 degrees C.)

TIME IN MINUTES	RICE WEEVILS Mgs./gm.	CIGARETTE BEETLES Mgs./gm.	YELLOW MEALWORMS Mgs./gm.	CONFUSED FLOUR BEETLES Mgs./gm.	GERMAN COCKROACHES Mgs./gm.
2	.160	.592	1.13	—	3.01
3	—	—	—	4.17	—
5	.223	.820	2.61	5.89	—
6	—	—	—	—	5.45
10	.304	1.07	4.08	8.66	7.06
15	.376	1.27	5.08	10.1	8.50
20	.443	1.45	5.77	10.8	9.63
30	.558	1.77	6.55	11.4	11.2
40	.666	2.05	6.94	11.6	12.1
60	.865	2.55	7.27	11.7	13.2
80	1.06	2.99	7.41	—	13.7

corne (F.); at several different pressures of hydrocyanic acid and for various time intervals at both 20 degrees and 30 degrees C. Mature larvae of *T. molitor* were used in these experiments. The other species were tested in the adult stage. As it is not the purpose of the present paper to relate sorption of hydrocyanic acid to age or sex of the insects, but merely to give examples of types of sorption among the five species and their obvious differences, individuals comprising a sample were taken at random from stock cultures. The weight of the sample of insects taken ranged from 0.45 to 2 grams, depending on the capacity of the species to sorb hydrocyanic acid. Numbers of insects per sample ranged from about 10 (cockroaches) to 1200 or 1300 (rice weevils).

When the results for the several species at the same pressure of hydrocyanic acid are compared, it is found that there are pronounced differences among them, both in the manner in which the hydrocyanic acid is sorbed and in the amounts taken up. The results for a pressure of hydrocyanic acid equal to 47.5 mm. (70.2 mgs. per liter)[3] are listed in table 1. The quantities sorbed in the different times are given in milligrams per gram of insect. A series of results on a species represents a single run on one sample of that species.

When these sorption values are plotted against the time, a smooth curve, exponential in character, is obtained for each insect, fig. 2. In all cases this curve gradually flattens out and becomes parallel to the time axis as the insect becomes saturated with hydrocyanic acid. The time required for the insects to obtain their saturation value varies considerably with the different species. For instance, confused flour beetles have taken up their saturation values after about 40 minutes, while rice weevils and cigarette beetles continue to take up small quantities of hydrocyanic acid for long periods of time.

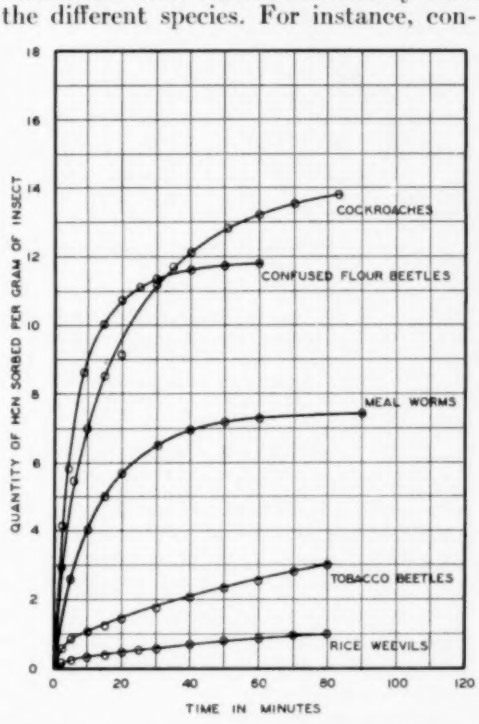

FIG. 2.—Showing the different quantities of hydrocyanic acid sorbed by several species of insects. Partial pressure of hydrocyanic acid equals 47.5 mm. in all cases.

[3] One liter of hydrocyanic acid vapor at a pressure of 1 mm. at 20 degrees C. weighs 1.478 milligrams, and, at 30 degrees C., 1.429 milligrams.

It will be seen both from table 1 and from fig. 2 that confused flour beetles take up much larger quantities of hydrocyanic acid than rice weevils. This explains to a large extent the reason why confused flour beetles are so much more easily

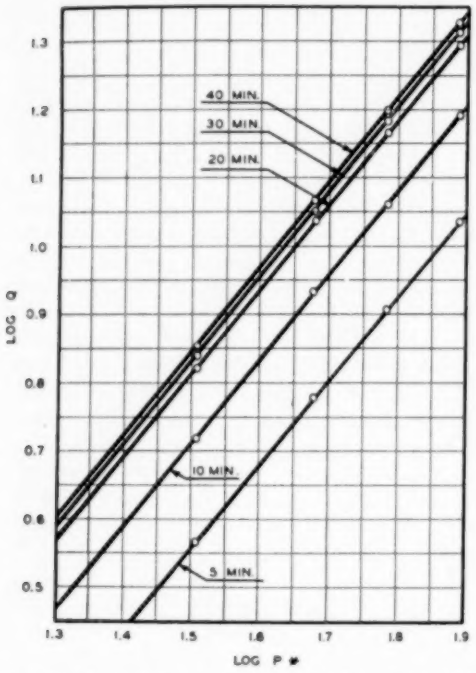

FIG. 3.—Log of the quantity of hydrocyanic acid sorbed plotted against the log of the partial pressure of hydrocyanic acid at several periods of exposure for confused flour beetles.

killed with hydrocyanic acid than are rice weevils. Unfortunately the concentration of hydrocyanic acid that will kill 99 per cent of the confused flour beetles (0.5 milligrams per liter of hydrocyanic acid in a 10-minute period) is so low that it is not possible to determine how much hydrocyanic acid is sorbed from this dosage. Consequently we are not able to determine whether or not the internal dose necessary to kill rice weevils is greater than that required to kill confused flour beetles. We do know, however, that confused flour beetles will sorb from a low concentration of the vapor as much hydrocyanic acid as will rice weevils from a considerably greater concentration. Our measurements show that confused flour beetles will sorb 5.27 mgs./gm. from a concentration of 32 mm. in a 10-minute period, whereas rice weevils sorb only 0.444 mgs./gm. from a concentration of 77 mm. in the same period of time.

The ability of the insect to sorb hydrocyanic acid is therefore a very important factor in the killing of the insect. This fact is also brought out by a comparison of the quantities sorbed and the concentrations required to kill each of the species studied. In every case it will be found that the species which sorbs the smaller quantity of hydrocyanic acid is the one that requires a greater concentration of the vapor to cause death. In other words, we believe that the ease of killing with hydrocyanic acid does not depend so much upon its actual toxicity, which is, of course, great for all forms of animal life, as it does upon how readily the hydrocyanic acid is sorbed by the insect.

Measurements have also been made at several different pressures of hydrocyanic acid with each species in order to determine how the quantity sorbed varies with the pressure of hydrocyanic acid. When the logarithms of the quantities sorbed during a given time are plotted against the logarithms of the corresponding pressures of hydrocyanic acid, an approximately straight line results, fig. 3. This fact indicates that the sorption of hydrocyanic acid by these insects follows an equation of the type

$$q = kP^{*1/n} \qquad (6)$$

since, by taking logarithms of both sides of this equation,

$$\log q = \log k + 1/n \log P^* \qquad (7)$$

it is evident that a straight line results when $\log q$ is plotted against $\log P^*$. In these equations, q is the quantity sorbed in milligrams of hydrocyanic acid per gram of insect, k is the proportionality constant, P^* is the partial pressure of hydrocyanic acid over the insect in millimeters of mercury, and n is a constant dependent upon the insect used. This is illustrated for the case of the confused flour beetle in fig. 3, where $\log q$ has been plotted against $\log P^*$ for the times 5, 10, 20, 30 and 40 minutes.

The equations of these lines have been determined since they are very useful in calculating the amount of hydrocyanic acid sorbed for any pressure within the limits of the measurements (30 to 80 mm.). This is accomplished by dividing the data for a given line into two groups

Table 2.—Coefficients for the equation, Log q = log k + 1 : n log P*.

TIME IN MINUTES	CONFUSED FLOUR BEETLES		RICE WEEVILS		COCKROACHES		MEALWORMS	
	Log k	$1/n$	Log k	$1/n$	Log k	$1/n$	Log k	$1/n$
5	−1.247	1.203	−2.039	.817	−.749	.870	—	—
10	−1.083	1.202	−1.868	.800	−.517	.817	−.460	.659
20	− .991	1.206	−1.685	.789	−.350	.792	−.286	.659
25	—	—	—	—	−.327	.799	—	—
30	− .956	1.206	−1.596	.798	—	—	−.244	.680
40	− .949	1.202	−1.505	.790	—	—	—	—

as nearly equal as possible, and forming two equations similar to (6) by summation. These are then solved simultaneously in order to determine the value of the constants, log k and $1/n$. Once these coefficients have been determined, it is a simple matter to find the quantity sorbed by a particular insect in a given time and pressure by substituting the pressure in the appropriate equation and solving for log q. The coefficients of these equations for confused flour beetles, rice weevils, cockroaches and mealworms are given in table 2.

The effect of temperature upon the sorption of hydrocyanic acid by insects was determined by running duplicate experiments at 20 degrees and 30 degrees C. with confused flour beetles, rice weevils and cockroaches. It was found that in all cases the sorption was considerably lower at 30 degrees C. than at 20 degrees C. The results obtained for rice weevils are listed in table 3; entirely similar results were obtained with both confused flour beetles and cockroaches. As in table 1, each series of results represents a run on one sample of insects.

Table 3.—Effect of temperature on the sorption of hydrocyanic acid by rice weevils.

	TIME IN MINUTES	MGS/GM. SORBED AT 20° C.	MGS/GM. SORBED AT 30° C.	PER CENT DECREASE IN SORPTION $\left(\frac{q_{20°}-q_{30°}}{q_{20°}}\times 100\right)$
P^* = 48.6 mm.	10	.303	.197	35.0%
	20	.442	.280	36.8
	40	.672	.421	37.4
P^* = 80.7 mm.	10	.454	.316	30.4
	20	.660	.453	31.4
	40	1.000	.677	32.3

SUMMARY.—Measurements of the quantities of hydrocyanic acid sorbed during different time intervals and at several pressures of hydrocyanic acid have been made on five different species of insects.

The amount of hydrocyanic sorbed varies with the species; those insects which are generally known to be difficult to kill were found to sorb smaller quantities of hydrocyanic acid than those species which are easily killed.

The sorption of hydrocyanic acid by insects was found to follow the equation

$$\log q = \log k + 1/n \log P^*$$

over the range of pressures used in the tests.

The amount of hydrocyanic acid sorbed was found to be considerably greater at 20 degrees C. than at 30 degrees C.—12-17-37.

JAPANESE BEETLE infested areas at Fort Wayne and South Bend, Indiana, were placed under quarantine by that state on January 8.

PEACH mosaic disease quarantines of Colorado and Texas were revised, in standardized form, in January to include areas found infected in 1937: one county in Oklahoma, one new county each in California and New Mexico and several in Arizona and Texas.

Toxicity of Hydrogenated Pyrethrins I and II to the Housefly

H. L. Haller and W. N. Sullivan, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine*

The researches of Staudinger & Ruzicka (1924) on pyrethrum flowers have shown that the insecticidal action of pyrethrin I and pyrethrin II, the toxic principles of these flowers, is for the greater part destroyed by minor changes in their molecules. Thus, the catalytic hydrogenation of a crude pyrethrin concentrate yielded a product that was insecticidally inactive. Likewise the tetrahydropyrethrin I which was obtained on condensation of tetrahydropyrethrolone and chrysanthemum monocarboxylic acid was nontoxic. Condensation of pyrethrolone with acids other than the chrysanthemum acids or esterification of chrysanthemum acid with alcohols closely related to pyrethrolone, as well as with other alcohols, yielded products that were without effect or possessed only slight toxicity. In all these experiments, Staudinger & Ruzicka used the cockroach, probably *Blattella germanica* (L.), as the test insect. No attempt was made to obtain precise entomological data, the emphasis being rather on the isolation and identification of the toxic principles of pyrethrum flowers.

Since these excellent pioneer studies were made, more precise methods for the evaluation of pyrethrum flowers as an insecticide have become available. Also it is now generally recognized that organic insecticides may be highly specific; that is, a compound may be very toxic to one insect and not to another. Moreover, it is possible that, whereas slight chemical changes in the structure of an organic compound may destroy almost completely its toxicity for a certain insect, they may have no effect on its toxicity for another insect.

The Present Experiment.—The Division of Insecticide Investigations has been engaged for some time in a study of the chemistry of pyrethrum flowers. One object of these studies is the preparation of pure pyrethrin I and pyrethrin II in unaltered form so that they may become available to the entomologist for studies on their relative toxicity. Although this object has not yet been realized, some progress has been made. A procedure has been developed, and described in detail elsewhere (LaForge & Haller 1935), whereby it is now possible to prepare pyrethrin concentrates high in total pyrethrins and fractions in each of which one of the pyrethrins predominates.

With such concentrates available, it seemed of interest to determine the effect on the toxicity to the housefly *Musca domestica* L. of pyrethrins that had been subjected to catalytic hydrogenation.

Materials and Methods.—Two pyrethrin concentrates were used, one in which pyrethrin I predominated and the other largely pyrethrin II, as indicated in table 1. Pyrethrin I was determined by the method of Seil (1934), and pyrethrin II by the method of Haller and Acree (1935). Two solutions of each concentrate in highly refined kerosene were prepared, each containing 5 mg. of total pyrethrins. In their preparation, one solution of each concentrate was allowed to absorb catalytic hydrogen before being dissolved, whereas the other was untreated; 70 cc. were absorbed by the concentrate in which pyrethrin I predominated and 100 cc. by the one in which pyrethrin II predominated. These stock solutions were diluted with kerosene to give the desired concentration of total pyrethrins.

The toxicity tests were made on the Campbell turntable (1935) as subsequently modified. After the flies had been in the spray chambers 10 minutes, they were transferred to observation cages. The flies that remained on the floor of the observation cages at this time were considered "knocked down." If most of the flies lay on the floor of the cages, a good "knockdown effect" was recorded; if most of the flies appeared normal or only slightly groggy, a poor knockdown effect was recorded. The knockdown effect obtained by this method is similar to but not exactly the same as that obtained by the Peet-Grady method (Anonymous 1932). The mortality of the flies was determined 24 hours after the spray application. The results are based on 5 tests of approximately 100 flies each. Flies

Table 1.—Comparison of the toxicity to house flies of pyrethrin concentrates that have been subjected to catalytic hydrogenation with toxicity of untreated concentrates.

Concentrate	Concentration of Pyrethrins* I Per Cent	II Per Cent	Chemical Treatment	Concentration of Pyrethrins Mg. Per cc.	"Knockdown Effect" 10 Minutes After Spraying	Mortality After 24 Hours Per Cent
1	63.2	6.5	None	1	Good	35
				2		64
				3		82
			Hydrogenated	1	Poor	14
				2		23
				3		29
2	5.4	83.7	None	1	Good	12
				2		17
				3		23
			Hydrogenated	1	Poor	14
				2		21
				3		14
Checks (Kerosene Alone)	—	—	—	—	Poor	7

* The composition of the concentrates was otherwise unknown.

sprayed with kerosene alone were used as checks.

RESULTS AND CONCLUSION.—The results, given in table 1, show that both pyrethrin I and pyrethrin II have good "knockdown effect" against flies and that this effect is for the greater part destroyed when the pyrethrins are subjected to mild catalytic hydrogenation. Hydrogenation also materially reduces the mortality caused by the concentrate in which pyrethrin I predominates. The mortality caused by the concentrate in which pyrethrin II predominates was low and was not materially reduced by hydrogenation. The mortality caused by this sample was so low before hydrogenation that a marked reduction would not normally be expected.

A comparison of the mortality caused by these two pyrethrin concentrates before hydrogenation indicates that the pyrethrin concentrates in which pyrethrin I predominates are more toxic to houseflies than those in which pyrethrin II predominates.—12-17-37.

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Staudinger, H. and L. Ruzicka. 1924. Insektentötende Stoffe I. Über Isolierung und Konstitution des wirksamen Teiles des dalmatinischen Insektenpulvers. Helv. Chim. Acta **7**: 177–201.

THE STATE BOARD of Agriculture of Oklahoma issued a quarantine proclamation on December 11 relating to the phony peach disease in an area within that state and also to infected areas in other states. Texas placed a standardized quarantine relating to the disease on January 10.

THE OREGON State Department of Agriculture recently repealed its quarantines relating to gladiolus thrips in other states, to the root-knot nematode in California and to the holly scale in Oregon, having determined that these quarantines were no longer necessary.

Complexity of Calcium Arsenate as Revealed by Chemical Analysis of Fractions of Different Particle Size

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A chemical examination of 22 brands of commercial calcium arsenate by Nelson & Cassil (1937) showed considerable variation in composition which appeared to be correlated with the particle size. Because of the variability in the manufacturing processes there were numerous exceptions to this correlation, but the tendency was for the finest material to have the least water-soluble arsenic as determined by the Geneva method (Pierce, Norton & Chapman 1935) and the highest ratio of arsenically combined calcium oxide to arsenic oxide. It seemed that this might be more definitely proved if one sample could be separated into its fractions of different particle size and some of the fractions subjected to chemical analysis.

For this investigation a commercial sample (15 pounds) known to contain particles over a large size range was separated into several fractions in a centrifugal air classifier. This method has the advantage that no chemical change is effected, as might occur if the separation was done by water elutriation or other means where solvents are used. The finest, a medium and the coarsest fraction were chosen for analysis. Since some of the intermediate fractions were discarded, these three samples do not represent the original divided into three parts.

PARTICLE-SIZE DISTRIBUTION.—The particle-size distribution was determined by sedimentation analysis (Goodhue & Smith 1936) on the original and the three fractions. The results are shown graphically in fig. 1. The medium fraction is similar to the original, which is nearly the mean of the two extreme samples. While the separation of these fractions is not complete, there is actually a very great difference in the average particle size of the coarse and the fine samples.

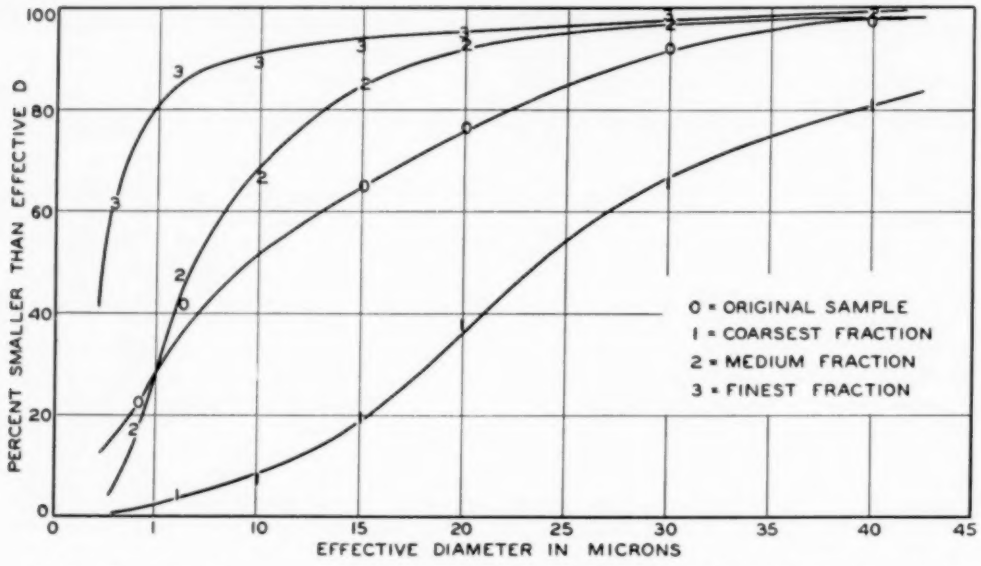

FIG. 1.—Cumulative frequency curves showing relation of percentage by weight to effective diameter of particles of calcium arsenate. The numerals represent the points determined experimentally.

In the calculation of particle-size distribution it was necessary to know the densities of the various fractions. These figures, which are shown in table 1, decrease regularly with decrease in particle size. Because of the evident difference in the specific bulk of the different fractions,

the loose bulking values were also determined and included in table 1. The variations in these values is also correlated with particle size.

Table 1.—Densities and bulking values of a sample of calcium arsenate and of several of its fractions.

SAMPLE	DENSITY G. per cc.	LOOSE BULKING VALUE Cu. in. per lb.
Coarse	3.00	34.8
Medium	2.91	75.0
Fine	2.81	94.5
Original	2.915	59.4

RESULTS OF CHEMICAL ANALYSIS.—A complete chemical analysis of the original sample and the three fractions is given in table 2. Partly because of their low density, the free lime (calcium hydroxide) and calcium carbonate accumulate to a greater extent in the fine fraction, whereas very little remains in the coarse fraction.

At first glance it might appear that the transfer of these materials would account for all the variation in the chemical analysis, but a closer examination shows that this is not the case. In the first place, free lime has little effect on the water-soluble arsenic as determined by the Geneva method (Pierce, Norton & Chapman 1935), except as a diluent in the sample. The values for total lime have been converted to arsenically combined calcium oxide by subtracting the calcium oxide occurring as free lime and calcium carbonate in the sample. Even after this correction, which is very large on the fine sample, there still remains a considerable difference in the chemical composition, as shown by the molecular ratios of calcium oxide to arsenic oxide.*

The only determination that might be questioned is that for free lime. The only available method (Smith & Hendricks 1924) depends on the reaction of calcium hydroxide with benzoic acid in alcohol. The tetracalcium arsenate, because of its relatively basic nature, may also be slowly attacked by the acid and thereby increase the value obtained for free lime. The presence of less free lime in the fine sample, however, would indicate a still higher percentage of the tetracalcium arsenate and a more nearly complete mechanical separation.

The evidence presented here supports the theory that the finest particles of calcium arsenate, by virtue of their very large surface-to-volume ratio, continue to react with the free lime in the manufacturing process until a large part is transformed to the tetracalcium compound, which is considered to be the end product of the reaction.

Table 2.—The chemical composition of the various fractions of calcium arsenate and of the original sample.

SAMPLE	WATER-SOLUBLE ARSENIC, PER CENT	$CaCO_3$, PER CENT	FREE LIME AS CaO, PER CENT	TOTAL CaO, PER CENT	ARSENICALLY COMBINED CaO, PER CENT	TOTAL As_2O_5, PER CENT	MOLECULAR RATIO, CaO/As_2O_5
Coarse	18.8	4.78	2.1	39.30	34.53	48.35	2.92
Medium	9.7	13.79	8.8	45.52	29.01	37.18	3.20
Fine	3.0	12.92	17.6	50.49	25.68	30.30	3.47
Original	9.3	11.00	8.9	44.20	29.15	40.10	2.98

If water-soluble arsenic (Pierce, Norton & Chapman 1935) is responsible for the foliage injury caused by calcium arsenate, the fine fractions should be superior. The use of an air classifier makes it possible to separate sufficient material for field tests, and it is hoped that such a program will be undertaken by those interested in calcium arsenate.

SUMMARY.—A sample of calcium arsenate was separated into several fractions by an air classifier. The particle-size distribution was determined on the original sample and on three fractions, the finest and coarsest and one intermediate between these two. Analyses of these fractions showed a great variation in chemical composition, indicating that a chemical as well as a mechanical separation was accomplished. The fine particles were found to contain more arsenically combined calcium oxide than the coarse ones and, therefore, much less water-soluble arsenic.—12-17-37.

* It should be pointed out that a small variation in this ratio indicates a great variation in chemical composition. The ratio ranges from 2 in dicalcium arsenate to 4 in tetracalcium arsenate, as indicated by the names of the compounds.

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The Black Carpet Beetle, *Attagenus piceus* (Oliv.)*

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The black carpet beetle, *Attagenus piceus* (Oliv.), is a cosmopolitan pest of much greater importance than is generally supposed. Its common name conveys only a limited idea of its range of destructiveness. At present it is easily the most destructive and widespread of the so-called carpet beetles or buffalo moths, if one considers the country as a whole.

A tremendous amount of the injury caused by it is ascribed to ordinary wear and tear of clothing or to defective manufacturing. This is because its larvae spin no telltale webbing, are restless, prefer dark situations, crawl everywhere, and in many instances feed upon fabrics just long enough to cut here and there a few threads that start ravelings seldom associated with insect work. Furthermore, many people who are not familiar with the literature on the subject are surprised to find that the black carpet beetle is a general feeder upon all kinds of broken seeds and grain products and is usually present by thousands, if not literally by millions, in many establishments dealing in farinaceous supplies. Since the larvae may eat holes in food cartons and other containers, they open avenues for infestations which most grain beetles and moths cannot make themselves but which they are not slow to utilize. All things considered, the black carpet beetle is a very insidious pest to which entomologists do not give due credit for destructiveness.

ECONOMIC HISTORY.—The black carpet beetle was probably brought to North America in the baggage of the early colonists. It is believed to be a native of Europe. Apparently the first record of its occurrence in this country was made in 1806 by Melsheimer, a physician with the Hessian soldiers, who settled in Pennsylvania and turned his attention to entomology. Melsheimer (1806) listed it as *Dermestes cylindricornis* in his *A Catalogue of Insects of Pennsylvania*. Le Conte (1859) states, however, that the specimens in the Melsheimer collection were really *Attagenus megatoma* Fab., the name by which the black carpet beetle was known at that time. Erichson (1848), in his *Naturgeschichte der Insecten Deutschlands*, published complete in 1848, recorded its occurrence in homes in North America. Hagen (1881) stated in 1878 that it was a dangerous museum pest and had been destructive in homes in Cambridge, Mass., for several years.

The following year Lintner (1879) reported finding it feeding on carpets in Schenectady, N. Y. In 1882 he published (1882) a short account of its destructive habits and included a description of the larva and adult. Later he published (1885) a further account of the insect, observed that the adults fed on pollen and were abundant on *Spiraea* bushes in Albany, N. Y., and stated that the larvae bred in carpets, haircloth furniture, sofas, chairs, etc. Finally in 1893 he published (1893) a much fuller account of the insect and its ravages, including a fairly complete bibliography, and suggested the common name of black carpet beetle for it.

In 1882 Riley (1882) called attention to the peculiar felting found in pillows infested with the black carpet beetle. The feeding of the larvae results in fragments

* The information presented in this paper was secured prior to 1930 during the investigational work of the Division of Stored Product Insects of the Bureau of Entomology.

of feathers collecting on the ticking and forming a thick layer of a feltlike material. This type of felting has since been reported by many observers.

Fernald (1889) in 1889 referred to the insect as the "pitchy carpet beetle" and stated that there was one generation a year and that larvae found in June transformed in May of the following year.

Johnson (1895) in 1895 stated that a Maryland miller had reported the appearance in his mill of thousands of the adults. The insect had been breeding in flour dust and sweepings. Johnson placed larvae of the black carpet beetle in corn meal and wheat flour and reared them through to adults. That same year Chittenden (1895) reported finding the larvae in cereals of various kinds and seriously injuring bolting cloth in a mill at Georgetown, D. C. He bred the insect in flour, meal and timothy seed and found that the developmental period from egg to adult covered two years. Previous to this time the black carpet beetle was not known as a pest of cereals.

In 1896, Howard (1896) gave an account of the history of the beetle in North America, together with brief notes on its biology. The following year Chittenden (1897) gave a more extensive account of the insect. He stated that it was known in this country as early as 1806. He reported finding the insect in middlings, flour, meal and various kinds of seeds, and stated that injury to bolting cloth by the larvae had been noticed in a Georgetown, D. C., mill for the past 50 years. As other insects injure bolting cloth, one may well question the accuracy of the statement involving the 50-year period.

Felt (1899) in 1899 described the work of the larvae on a whalebone cane. The cane was so badly damaged that it had fallen apart, and at one end only a slender piece remained intact.

Dean (1913) in 1913 stated that the larvae cut cotton, jute and paper bags and bolting cloth in machines that lay idle. Fletcher (1917) reported in 1917 that in India the beetles took from one to three years to complete development.

Many references to the black carpet beetle are found in current entomological literature, but usually they are merely records of the occurrence of the larvae in various situations and do not add to our knowledge of the biology. The most comprehensive account of the biology of the black carpet beetle that has been given to date was published by Back (1923). He found that in heated houses in the vicinity of Washington, D. C., the adults appeared in greatest abundance during April and May, but were found as late as July. They lived for from 3 to 35 days. The eggs hatched in from 6 to 10 days, and the larval period lasted for about a year. The pupal period ranged from 6 to 16 days, and a majority of the beetles reared had one generation a year.

SYNONYMY.—The black carpet beetle was described as *Dermestes piceus* in 1790 by Olivier (1791), who recorded finding it in the *chantiers* about Paris. Eight years later it was described by Fabricius (1798) as *Dermestes megatoma*, the name by which it was commonly known for many years. Erichson (1848) in 1846 referred it to Latreille's genus *Attagenus*, and Jayne (1882) in 1882 stated that *megatoma* Fab. was a synonym of *piceus* Oliv.

The full synonymy as given by Dalla Torre (1911) in 1911, with slight changes by Arrow (1915) in 1915, is as follows:

piceus Oliv., Entom. II, 1790, nr. 9, p. 10, t. I, f. 4.

brunneus Falderm. Fn. Transcauc. I, in Nouv. Mem. Soc. Nat. Moscou IV, 1835, p. 227.

fulvipes Muls. et Rey, Hist. Nat. Col. Fr. Scuticoll., 1867, in Ann. Soc. Linn. Lyon (n.s.) XI, 1867 (1868), p. 71.

obliquus Rey, Exchange V, 1889, p. 59.

sordidus Heer, Fn. Col. Helv. I, 1838–42, p. 438.

var. *dalmatinus* Küst., Käf. Eur. X, 1847, nr. 44.

marginicollis Küst., Käf. Eur. XII, 1847, nr. 76.

var. *megatoma* F., Ent. Syst. Suppl. 1798, p. 71.

macellarius Duftschm., Fn. Austr. III, 1825, p. 39.

piceus Reitt., Verh. Zool.-Bot. Ges. Wien XXX, 1880, p. 75.

stygialis Muls. et Rey, Hist. Nat. Col. Fr. Scuticoll., 1867, in Ann. Soc. Linn. Lyon (n.s.) XV, 1867 (1868), p. 73.

japonicus Reitt., Deutsche Ent. Zeitschr. XXI, 1877, p. 375.

FOODS.—The foregoing statements indicate that the black carpet beetle has a wide range of foods. In the main, these foods fall into two groups, (1) those consisting of seeds, grains and anything made

from them and (2) such animal products as wool, hair, fur, feathers, horn, dried meat, dead insects, casein and dried milk, or supplies into the manufacture of which these enter. It is probably true that farinaceous materials are responsible for the development of many more specimens than are clothing, furs and house furnishings. Among a long list of objects recorded as found infested by the Bureau of Entomology and Plant Quarantine may be mentioned woolen rugs and clothing, silk clothing, carpeting, felts, furs, skins, yarn, velvet, feathers, hair-filled mattresses and upholstered furniture, wool-filled blankets, house insulations containing sheep wool and cattle hair or binders of farinaceous materials, meat and insect meal, kid leather, milk powders, casein, books, birds' nests, cayenne pepper, beans, peas, corn, wheat, rice and a long list of seeds and seed products.

LIFE HISTORY.—A study of over 1000 specimens, of which 565 were reared from egg to adult, is the basis for the conclusions presented here. The writers regret that their records of egg laying and of the effect of food upon development and mortality are very incomplete.

ADULT LONGEVITY.—Adult beetles in houses in Washington, D. C., begin to be noticed as early as the last week of April and may be found in greatest numbers during hot spells in May and early in June, when they fly about also out of doors and are seen on window screens during the heat of the day. By the middle of June their numbers become less. Adults may be present in small numbers during February and late in June and stray adults during July and August. In northern states the peak of emergence probably falls in June.

When the adult sheds the pupal skin it is reddish in color. It may be several days before this color darkens through the shades of brown to assume the normal black color. During this period, and often for much longer, the adult beetle remains quiescent in the pupal and the last larval skins which partially envelop it. In fact, the adult beetle may remain thus in the pupal skin from 2 to 20 days before suddenly finding its legs and departing hurriedly. In a study of 304 adults it was noted that the number of days individuals remained in the pupal skin was as follows (number of individuals in parentheses): 2 (2), 3 (16), 4 (44), 5 (35), 6 (39), 7 (36), 8 (18), 9 (13), 10 (13), 11 (20), 12 (28), 13 (27), 14 (8), 15 (3), 19 (1) and 20 (1).

These data, secured between May 15 and June 28, give no clue to the reason for the variation in the time spent in the pupal skin. The specimen remaining in the pupal skin longest, 20 days, shed its pupal skin June 4 but did not leave it until June 24. Forty-eight others, emerging June 1 to 5 remained in the pupal skin the following number of days: 2 to 3 (5), 4 (10), 5 (4), 6 (19), 7 (6), 8 (2), 10 (1) and 15 (1). The adults remaining only two days in the pupal skin matured on June 19 and June 21, respectively, but 38 others maturing on the same dates remained in the pupal skin as follows: 3 days (7), 4 days (17), 5 days (9), 6 days (3) and 7 days (2).

No adult was found that lived more than 35 days. The average length of life is probably much less when beetles are confined to the areas in which the larvae have developed. It is possible that access to the pollen of flowers adds to the longevity. The length of life of 66 specimens held in the laboratory during late April, May and June ranged from 1 to 35 days; the number of days lived by these beetles (numbers of individuals in parentheses) is as follows: 1 (1), 2 (2), 3 (3), 4 (2), 6 (10), 7 (4), 8 (1), 9 (4), 10 (2), 11 (4), 12 (1), 13 (3), 14 (3), 15 (2), 16 (6), 18 (4), 19 (2), 20 (1), 21 (2), 23 (4), 24 (2), 30 (1), 35 (2).

OVIPOSITION.—In attempting to determine facts relating to the daily rate of egg laying and total oviposition capacity, 1020 adults were captured at random at windows, or as they emerged from cultures, between May 12 and June 7. Because of lack of time due to routine work and because of the difficulty in separating the sexes by casual observation, the beetles were placed, without regard to sex, in groups of five each, in vials with pieces of mohair furniture covers and casein. The mohair was chosen because the eggs deposited in the pile are easily seen and are not easily dislodged during careful examinations.

In table 1 are given the egg-laying records of 26 groups of five beetles each, selected from a total of 204 similar group records. Many groups not recorded in this table laid either no eggs or only a very

few. However, it is thought that the records selected for inclusion in table 1 are nearly typical of true conditions. While the exact emergence dates of all except the adults of the last 10 groups are unknown, it is believed that the beetles were captured before egg laying was fairly under way. If it be assumed that the sexes are evenly divided, the 26 groups contained 65 females which laid a total of 3,281 eggs, or an average of about 50 eggs each. If one makes the same assumption as to sex and considers only the 1,327 eggs laid by the 10 groups of known age, the average number of eggs per female is 53.

Table 1.—Number of eggs deposited by groups of five adult *Attagenus piceus*, selected without regard to sex and placed in vials with mohair cloth and casein, Washington, D. C.

Date of Emergence	Date of Capture	Number of Eggs Deposited on the Given Dates*																
		May														June		
		16	17	18	19	20	21	22	23	24	25	26	28	29	30	31	11	12
	May 12	9	10	0	0	0	34											
	May 12	0	0	0	29	0	41											
	May 12	21	28	0	35	24	15											
	May 12	25	16	20	13	32	0	9										
	May 14	0	44	19	2	0	0	38	0	0	0	7						
	May 14	0	26	0	8		42	3	14	6								
	May 14	0	12	20	37		76	19										
	May 15	0	41	0	0	42	0	0	32	0		25						
	May 15	0	35	0	11	26	1	23	0	0		8						
	May 15	0	0	0	8	35	0	42	0	0		39						
	May 16	0	18	0	4	45	20	25	0	0		21	1	1				
	May 16	0	0	26	0	6	34	5	8	19		4	14	0				
	May 17			16	12	18	0	38	3	0		44	32	0	36	0	17	13
	May 17			0	0	0	1	57	6	0		32	31	0	0	0	0	0
	May 18				0	0	17	23	29	0		31	33	12	0	0	0	0
	May 18				0	0	0	0	0	27	0	0	48	15	0	0	0	0
May 17	May 18				0	0	0	0	12	29		12	39	15	0	0	0	0
May 17	May 18				0	0	0	0	0	39		39	96	26	0	6	0	0
May 17	May 18				0	0	0	0	0	9		9	30	2	23	0	0	0
May 18	May 19					0	0	0	0	7		26	41	0	28	4	12	0
May 18	May 19					0	0	0	0	0		50	37	9	0	23	0	0
May 19	May 21							0	0	0		35	0	53	31	0	2	25
May 19	May 21							0	0	0		29	0	85	11	0	1	13
May 19	May 21							0	0	0		11		107	36	0	0	0
May 19	May 21							0	0	0		46	33	29	0	0	0	5
May 19	May 21							0	0	0		61	40	24	17	18	0	0

*Records were made on only two groups on May 25, and no records were made on May 27; any eggs that were deposited on these dates are included in the records for the days that followed.

LENGTH OF THE EGG STAGE.—Eggs of the black carpet beetle were found to hatch in from 6 to 11 days during May and June. A large proportion of several hundred eggs hatched on the tenth and eleventh day after oviposition.

LARVAL DEVELOPMENT.—It has been stated in the literature mentioned that the larval development requires from one to three years, with the majority of the larvae, under favorable food conditions, requiring about 1 year. Of 565 rearing records, 25 that represent average conditions when the larvae are fed upon a suitable food, such as casein, are given in table 2. Each larva upon hatching was placed (before its first molt) in a vial by itself with ample casein, and the molted skins were removed as cast. It would seem that larvae molt from 5 to 11 times during growth, but the writers believe that, under adverse food and climatic conditions which might extend considerably a normal development, the number of molts could be increased close to 20. The late F. H. Chittenden, in an undated note, stated that a larva hatching in May in Washington and held under most favorable conditions was about one-quarter grown in four weeks, about one-half grown in eight weeks and reached approximate maturity in size at the approach of cold weather. The larvae, the development of which is recorded in table

Table 2.—Development of larvae of *Attagenus piceus* (Oliv.) that hatched about June 1 and were placed under observation before molting the first time.

SPECIMEN	DATE OF LARVAL MOLTS											PUPATION	ADULT EMERGENCE
1	June 8	June 24	July 15	Aug. 10	Sept. 7							Apr. 9	Apr. 22
2	June 4	June 19	July 14	July 31	Aug. 22	Sept. 21						May 20	June 2
3	June 3	June 21	July 10	July 25	Aug. 16	Sept. 11	Mar. 26	Apr. 30				May 26	June 11
4	June 2	June 23	July 19	Aug. 14	Sept. 13	Apr. 11						May 25	June 3
5	June 1	June 18	July 4	July 23	Aug. 20	Sept. 13	Sept. 27	Mar. 29	Apr. 5	May 14		June 5	June 16
6	June 2	June 14	July 3	July 22	Aug. 20	Sept. 24	Nov. 4					Apr. 25	May 9
7	June 8	June 26	July 1	July 17	Aug. 5	Aug. 16	Sept. 11	Apr. 18				May 31	June 9
8	June 3	June 19	July 1	July 16	July 30	Aug. 20	Sept. 25					Apr. 18	May 1
9	June 1	June 17	July 13	July 29	Aug. 21	Sept. 26	Nov. 17					Apr. 20	May 3
10	June 4	June 22	July 7	July 24	Aug. 11	Sept. 9						Apr. 2	Apr. 20
11	June 3	June 19	July 2	July 22	Aug. 12	Sept. 10	May 25					June 7	June 20
12	June 5	June 20	July 3	July 20	Aug. 21	Sept. 26	Mar. 17					May 10	May 21
13	June 2	June 14	July 4	July 15	Aug. 3	Aug. 29						Apr. 3	Apr. 18
14	June 3	June 18	July 4	July 20	Aug. 4	Aug. 23	Sept. 21	May 20				June 14	June 24
15	June 7	June 23	July 6	July 19	Aug. 21	Sept. 25	Mar. 10	Apr. 17				May 22	June 1
16	June 3	June 20	July 1	July 13	July 26	Aug. 5	Aug. 16	Sept. 4	Oct. 2	Apr. 25		June 1	June 10
17	June 1	June 14	July 3	July 16	July 27	Aug. 12	Aug. 31	Sept. 22	Apr. 8			May 22	June 1
18	June 7	June 19	July 2	July 15	July 27	Aug. 11	Aug. 24	Sept. 13	Oct. 19	Mar. 5	Apr. 20	June 1	June 10
19	June 4	June 18	July 1	July 12	July 25	Aug. 5	Aug. 19	Sept. 3	Sept. 30	Mar. 31		May 19	May 29
20	June 5	June 20	July 2	July 12	July 21	July 28	Aug. 12	Aug. 27	Sept. 15	Oct. 8	Apr. 10	May 22	June 1
21	June 2	June 12	June 22	July 5	July 22	Aug. 7	Aug. 31	Mar. 6				May 8	May 20
22	June 2	June 13	July 4	July 15	July 30	Aug. 21	Sept. 9	Apr. 18				May 28	June 8
23	June 4	June 19	July 10	July 24	Aug. 16	Sept. 1	Sept. 26	Apr. 2	May 19			June 11	June 18
24	June 5	June 18	July 3	July 19	July 28	Aug. 17	Sept. 14	Apr. 2				May 19	May 29
25	June 3	June 19	July 2	July 20	Aug. 6	Sept. 29	Apr. 19					May 23	June 2

2, represent this most rapid growth under favorable house conditions.

There is much evidence that some larvae require two and three years to reach maturity. The Bureau of Entomology and Plant Quarantine receives larvae throughout the winter months from many parts of the country, and these often are small, indicating that they are the progeny of adults maturing late or that they have lived under adverse food and temperature conditions. It is easy to believe this, for apparently larvae developing in the warmth of Washington with plenty of food show departures from normal.

Of 281 larvae, collected for experimental work early in July and apparently well grown, none pupated until May and June of the first following year, and a few not until the April–June period of the second following year. If the larvae hatched, as believed, during the summer of the year previous to their collection as well grown, they were approximately two and three years old when maturing as adults. One such larva, collected as well grown July 12, 1922, had molted by August 4 and October 11, 1922; May 7, June 11, July 20 and September 4, 1923; March 8 and May 4, 1924; and pupated on June 15, 1924. A second larva, also collected as well grown on July 12, 1922, had molted by July 29 and August 18, 1922; April 9, May 27, June 25 and September 11, 1923; and January 30, 1924; and died March 7, 1924. Of a lot of 51 larvae hatching June 5, 1922, 42 pupated during May and June, 1923, but 9 continued feeding until the spring of 1924. Two larvae hatching on June 5, 1922, and held separately in individual vials with scanty food, were transferred to fresh, abundant food on May 10, 1923. One thereafter molted on June 4 and August 18, 1923, and pupated April 6–9, 1924; the second, after being transferred to fresh food, molted on May 14, June 11, July 12 and August 22, 1923, and pupated on March 10, 1924. A third larva hatching on June 29, 1922, and held with scanty food until May 10, 1923, when it was transferred to ample food, molted May 29, June 23, July 24 and September 10, 1923, and March 10, 1924, and pupated April 12, 1924. A study of the long series of larval records shows that all larvae under observation in Washington, D. C., pupated during April, May or June, except three which pupated on July 2, 15 and 17, respectively. The capture of a few adults during February and March is evidence that pupation may occur during these months. The indications are that when conditions are not right for pupation during the April–June period the larvae live on until the next season, continuing to eat and molt.

LENGTH OF PUPAL STAGE.—The length of the pupal stage of 286 specimens pupating between April 21 and July 17, 1923, ranged from 9 to 24 days. Of this series, two specimens pupating on July 15 and 17 required 9 and 11 days, respectively, and 13 pupating between April 21 and 30 became adults in from 19 to 24 days. From 9 to 18 days were passed in the pupal stage by 259 specimens pupating between May 1 and June 10. One hundred twenty-one specimens, of which those in table 2 are a part, pupating between April 2 and July 2, 1920, required from 6 to 18 days (average 10.8 days) for pupal development. Twenty that pupated between April 8 and June 7, 1919, required from 7 to 15 days (average 10.8 days) for pupal development. According to these data the pupal stage may require from 6 to 24 days.

SUMMARY.—*Attagenus piceus* was described as *Dermestes piceus* in 1790 by Olivier from specimens collected in Paris. A native of Europe, it was brought to the American continent in the baggage of early colonists and was first recorded in the United States in 1806 by Melsheimer. Called the black carpet beetle for the first time in 1893 by Lintner, before it was known to feed upon other foods than those containing karatin, it has been saddled with a common name that conveys little of its wide range of foods of a farinaceous nature, or of its prime importance as a pest of dwellings and educational and industrial establishments. It is an insidious pest receiving the blame for but a small part of the injury for which it is responsible.

The eggs hatch in from 6 to 11 days during warm weather. Larvae reach maturity and pupate usually in about one year, but some for no apparent reason, and others because of adverse food and temperature conditions, have required two and three years. Larvae of known history have molted from 5 to 11 times, but adverse growth conditions may in-

crease the number of molts to about 20. Pupae mature in from 6 to 24 days. In Washington, D. C., in heated buildings, a large majority pupate during the April–June period, although a few pupate at other times, as early as February and March and as late as July 17. After partially shedding the pupal skin after the manner characteristic of *Anthrenus*, *Dermestes* and *Attagenus*, the adults may remain quiescent within it for from 2 to 20 days before becoming active.

Adults are attracted to daylight, are found about windows and flying out of doors in the sun, often upon screens and sometimes feeding upon the pollen of flowers, especially those of *Spiraea* bushes. Adults may live as long as 35 days. In some instances females under observation have started to lay eggs in less than one week after emergence and have laid an average of about 53 eggs within another week's time. Ovipositing females seldom live more than two weeks under house conditions, if one can judge from laboratory records.—12-17-37.

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Flooding for the Control of Wireworms in California

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Preliminary experiments under cage conditions at Alhambra, Calif., during 1929 and 1930, involving principally the sugar-beet wireworm, *Limonius* (*Pheletes*) *californicus* (Mann.), indicated the possibility that the flooding of soil containing wireworms could be practiced to aid in the control of these pests.

The results were so promising that in 1930 a field test was performed in which a series of plots were flooded continuously for 5, 10, 15 and 20 days. A comparison of the surviving wireworm populations in

* The authors wish to express appreciation for the assistance given by A. F. Howland and C. S. Guy in conducting the experiments reported in this paper.

the treated plots soon after the conclusion of the treatment showed that, under the conditions of this test, the flooding operation had been of but little value in causing wireworm mortality. Consequently, no further experiments on flooding were performed at that time.

Interest in this phase of the wireworm problem was renewed in 1933, however, when information received by the authors from M. C. Lane, of the Walla Walla, Wash., field laboratory of this Bureau, and published later by Lane & Jones (1936), indicated that the degree of wireworm mortality obtained during flooding operations was influenced profoundly by prevailing soil temperatures. A review of the data compiled from the 1929–30 flooding experiments under cage conditions at Alhambra disclosed that a high mortality of wireworms had been attained when the soil temperatures were relatively high, although the influence of this factor had not been appreciated at the time.

EXPERIMENTS IN 1933.—In view of this new development the flooding experiments with wireworms were resumed at Alhambra during 1933 and arranged in such a manner as to determine the effect of soil temperature upon the wireworm mortality.

CAGE EXPERIMENTS.—In the first series of experiments, 20 wireworms were placed in the soil of each of eight screen cages, which were 15 inches high and 6 inches in diameter. These cages were then buried in a soil-filled tank so that their tops were level with the soil surface. Another set of eight cages, containing 20 wireworms each, was buried in a similar manner in a small field plot. Both sets of cages were flooded continuously from June 16 to 22. Soil temperatures were recorded at depths of 4, 8 and 12 inches, and each day one cage from each set (two cages on June 18) was removed and examined. The wireworms recovered from each cage were placed in moist soil and examined three to five days later to make certain whether they were living or dead. It was found that the daily temperature variation was greater at the 4-inch depth than at the 8- and 12-inch depths. The wireworm mortality obtained in each cage, together with temperature data at the 4-inch depth, is shown in table 1.

These results show an increasing percentage of wireworm mortality each day, but 100 per cent only in the field cages on the seventh day. Mean soil temperatures were slightly higher in the field than in the laboratory.

Table 1.—Effect of flooding on mortality of wireworms in screen cages buried in the soil, June 16–22, 1933.

No. Days Flooded	Temperature (° F.) at 4-Inch Depth						Per Cent Wireworms Dead	
	Laboratory			Field			Laboratory	Field
	Min.	*Mean*	*Max.*	*Min.*	*Mean*	*Max.*		
1	67	73	80	68	75	82	60	40
2	66	72	79	67	73	79	85	25
3	62	73	84	64	73	82	50	79
	62	73	84	64	73	82	90	65
4	63	72	82	64	74	84	89	65
5	64	72	79	66	75	84	95	85
6	64	74	85	66	74	83	90	95
7	65	73	80	69	77	86	95	100

Wireworms were present in the soil outside the cages in the field plot, and the effect of seven days of flooding was ascertained by examining 10 half-square-foot samples to a depth of 15 inches, four days later. Of the total of 50 wireworms found in these samples, 14 were in the top 6 inches of soil and all were dead, 14 were found in the 6- to 9-inch layer and 13 were dead, 12 were in the 9- to 12-inch layer and 3 were dead and 10 were in the 12- to 15-inch layer and only 1 was dead.

It will be noted that all wireworms above a depth of 6 inches were killed, but that a comparatively small percentage below 9 inches were affected. The mean soil temperature at 8 inches was 73.9° F. and at 4 inches 73.6° F.; so depth, not temperature, appeared to be the factor here.

In two additional experiments with the

screen cages, carried on the latter part of June, 1933, with mean soil temperatures of 71.7°, 73.1° and 73.3° F. at the 4-, 8- and 12-inch levels, respectively, the last live wireworm was recovered on the ninth and eleventh days. In the final laboratory plot experiment, with mean temperatures of 74°, 75° and 76.6° F. at the 4-, 8- and 12-inch depths, respectively, no live wireworms were recovered after the third day.

FIELD PLOT EXPERIMENTS.—A plot 40 by 600 feet, or 0.55 acre, was plowed 12 inches deep and then ridged to contain 48 basins, each approximately 17 by 20 feet. This plot was flooded continuously from July 12 to 22, 1933. The mean temperatures of the air and at the soil surface of the plot during the flooding period were 71.0° and 72.8° F., respectively. The mean soil temperatures at depths of 4, 8 and 12 inches were 73.9°, 73.1° and 71.2° F., respectively.

An examination of 25 half-square-foot samples of soil before flooding gave an average population of 11.7 wireworms per square foot. This figure probably is a little low, as 10 of the samples were taken only to a depth of 12 inches and later sampling showed that at least 10 per cent of the wireworms were in the soil stratum between 12 and 20 inches deep. The estimated population would therefore be approximately 12.8 wireworms per square foot.

On July 30, after the field had been plowed again, an examination of 20 half-square-foot samples to a depth of 18 inches revealed a surviving population of 1.1 wireworms per square foot. This represented a reduction of 91.4 per cent of the population before flooding.

An adjoining plot of 0.47 acre was plowed to a depth of 8 to 10 inches, ridged to form basins, and flooded from July 18 to 31. The mean temperatures of the air and at the soil surface of the plot during the flooding period were 74.0° and 77.2° F., respectively. The mean soil temperatures at depths of 4, 8 and 12 inches were 77.8°, 76.0° and 73.6° F., respectively.

The wireworm population from 25 half-square-foot samples before flooding was 12.6 per square foot, but this figure is considered to be low, since 10 of the samples were taken to a depth of only 12 inches. A more accurate figure would be 13.8 wireworms per square foot.

Twenty samples taken from the plot on August 9, to a depth of 18 inches, gave a population of 1.4 living wireworms per square foot, which represents a reduction of 89.8 per cent from the original population.

A young walnut orchard of 1.28 acres with a cover crop of wheat was disked and then plowed 12 inches deep on August 4. It was then ridged for flooding. An area about 10 feet square was ridged around each tree and left unflooded. The field was divided into four plots. Plot 1 was flooded from August 8 to 26. Difficulty was encountered in flooding plots 2 and 3. All basins were wet several times, but were not kept flooded until August 17. Plot 4 was wet first on August 11, but was not held under water until August 17. All flooding was stopped August 26. The mean temperatures of the air and at the soil surface of the plot during the flooding period was 73.4° and 72.5° F., respectively. The mean soil temperatures at depths of 4, 8 and 12 inches were 73.0°, 72.1° and 72.6°, respectively. The results of this experiment are shown in table 2. No explanation can be given for the low mortality, except possibly the irregularities in flooding.

Table 2.—Effect of flooding on mortality of wireworms in a young walnut orchard having a cover crop of wheat.

Plot No.	Days of Continuous Flooding	Wireworms per Sq. Ft. Before Flooding	Wireworms per Sq. Ft. After Flooding	Per cent Reduction in Wireworms
1	18	5.5	2.0	63.6
2	9	10.0	4.5	55.0
3	9	10.5	5.0	52.4
4	9	5.7	3.5	39.0

To test the effect of soil treatment before flooding, five plots, 27 by 30 feet, were prepared as follows: Plot 7 was furrowed 12 inches deep at intervals of 12 inches; plot 8 was furrowed 12 inches deep at 18-inch intervals; in plot 9 the soil was undisturbed, firm and well packed; plot 10 was subsoiled 18 inches deep and 12 inches apart; in plot 11 the entire area was plowed 12 inches deep.

Plots 7 and 8 were held under water continuously for 15 days beginning August 25. The mean temperature of the air during the flooding period of these two plots was 65.7° F., and the mean soil temperature 15 inches below the normal

Table 3.—Effect of flooding on mortality of wireworms in furrowed plots.

Plot No.	Wireworms per Sq. Ft. Before Flooding	Wireworms per Sq. Ft. After Flooding			Per Cent Reduction in Wireworms		
		Ridges	Furrows	Average	Ridges	Furrows	Average
7	13.6	1.6	3.6	2.6	88.2	73.5	80.8
8	10.0	.8	1.2	1.0	92.0	88.0	90.0

soil surface was 69.2° F., both underneath the bottom of the furrow and underneath the ridge. The results obtained in these plots are given in table 3.

Plots 9, 10 and 11 were flooded August 29 and kept under water for 14 days. Air and soil temperatures were essentially the same as for plots 7 and 8. In these plots there was no significant difference in the mortality from the different treatments, such mortality ranging from 82.5 to 86.6 per cent.

In general, the flooding experiments performed during 1933 indicated that continuous flooding for as long as 10 to 15 days killed up to 90 per cent of the wireworms. In only one field experiment was the mean soil temperature above 75° F., and in most experiments it ranged from 68° to 73° F.

EXPERIMENTS IN 1934.—Since the temperature of the soil appeared to be an important factor in the mortality of wireworms from flooding, in 1934 plots were located in the Sacramento Valley, where temperatures are ordinarily higher than in the vicinity of Alhambra. The field used, at Isleton, had suffered from wireworm damage for several years.

Each plot was 25 feet square. Six plots were plowed 12 inches deep previous to flooding, and two were left unplowed.

Table 4.—Effect of flooding in plowed and unplowed field plots on mortality of wireworms at different depths in the soil, Isleton, Calif., 1934.

Plot No.	Days Flooded	Wireworms per Sq. Ft. before Flooding	Mean Soil Temperature (° F.) During Flooding at Depth of:			Per Cent of Wireworms Dead at Depth of:			Average Per Cent of Wireworms Killed
			4 inches	8 inches	12 inches	0–6 inches	6–12 inches	12–18 inches	
First Series									
Plowed									
3	4	5.7	68.4	71.7	71.0	100.0	53.8	66.6	60.9
4	4	12.0	68.4	71.1	71.0	40.0	71.6	64.7	63.9
5	6	24.0	69.3	72.0	72.1	83.3	73.3	70.0	73.6
6	6	13.0	69.3	72.0	72.1	80.0	22.2	18.2	35.9
7	8	18.6	67.2	70.8	71.0	50.0	57.1	17.4	38.0
8	8	10.2	67.2	70.8	71.0	75.0	47.1	80.0	61.3
Average						*71.1*	*55.7*	*52.0*	*56.8*
Not Plowed									
1	6	3.6	66.9	70.0	69.8	25.0	66.6	50.0	45.4
2	6	6.6	66.9	70.0	69.8	0.0	100.0	43.7	55.0
Average						*25.0*	*85.7*	*45.0*	*51.6*
Second Series									
Plowed									
4A	4	16.8	69.1	70.8	69.1	69.2	51.5	55.0	56.0
6A	6	14.2	69.4	71.1	69.3	54.5	90.0	97.1	87.7
8A	8	11.4	68.6	70.4	68.8	81.8	94.7	94.1	91.5
Average						*69.4*	*73.6*	*84.5*	*77.0*
Not Plowed									
4B	4	13.5	69.1	70.8	69.1	88.9	42.3	85.7	63.3
6B	6	9.6	69.4	71.1	69.3	45.4	44.4	42.8	44.4
8B	8	9.2	68.6	70.4	69.8	63.6	66.7	75.0	68.1
Average						*64.5*	*50.0*	*72.7*	*58.7*
Average of six plots						*66.7*	*61.6*	*74.9*	*69.0*

Flooding was continuous for four, six or eight days, beginning June 29. One-half-square-foot samples, taken from the plots the day after flooding was stopped, were washed through fine screens, and the number of dead and live worms noted. The results are shown in table 4. Unfortunately, strong winds from the San Francisco Bay area during the entire period of the experiment caused relatively low temperatures; so a second series of plots were flooded beginning July 31. There were six plots 30 feet square, three plowed and three unplowed. The results ridged plots about 4 feet square, so that the tops were level with the soil surface. Two days later the plots were flooded. One plot was kept flooded continuously, and the other was filled with water each morning. In the second plot the surface water disappeared before evening. Beginning the second day, a cage was taken from each plot daily, allowed to dry out for five days, and then sifted for dead and live wireworms. Two similar cages were buried in moist soil nearby for checks. The data from these experiments are summarized in table 5.

Table 5.—Comparison of continuous and intermittent flooding on mortality of wireworms.

Days Flooded	Continuous Flooding			Intermittent Flooding		
	Mean Temperature		Per Cent of Wireworms Killed	Mean Temperature		Per Cent of Wireworms Killed
	4 inches deep	8 inches deep		4 inches deep	8 inches deep	
2	71.5	75.4	85	71.4	71.9	90
3	71.2	74.7	85	71.7	71.5	95
4	68.2	77.5	100	69.5	70.6	90
5	69.3	72.0	95	68.2	68.9	95
6	70.6	71.2	100	67.7	68.0	90
7	71.5	71.5	100	68.6	69.2	90
8	70.2	71.2	100	68.0	68.5	85
9	70.0	70.5	95	68.0	67.7	90
Average	*70.31*	*73.00*	*95.0*	*69.14*	*69.54*	*90.6*
Checks			*0*			*0*

(table 4) were slightly better and more uniform than in the first series. The maximum mortality of 91.5 per cent was obtained after eight days of flooding, and the mortality was higher in the plowed plots than in the unplowed plots.

From May 23 to August 5 a third series of experiments was conducted, in which fourteen plots in sandy loam soil near El Monte, Calif., were flooded for periods of four to ten days. Owing to cool weather the mean soil temperatures in the different plots ranged from 61° to 69° F. The wireworm mortality ranged from 27.5 to 86 per cent.

Intermittent Flooding.—Since it is difficult to keep the plots flooded all the time, and a large quantity of water is required, experiments were begun at Alhambra on May 21, 1934, to determine whether intermittent flooding would be satisfactory.

Eight wire-screen cages, of the size described previously, each containing soil and 20 wireworms, were buried in two

The continuously flooded plot gave a slightly greater mortality, probably because the water absorbed more heat and made the soil warmer. It seemed possible, however, that at higher soil temperatures intermittent flooding would give satisfactory wireworm mortality. This method requires less water and less labor than continuous flooding.

The experiment was repeated beginning on June 20, with similar results. In the continuously flooded plot the mean temperatures were 73.6° and 72.5°, with an average wireworm mortality of 87 per cent, while in the intermittent plot the temperatures were 69.2° and 69.1° F., with 82 per cent of the wireworms dead.

Water for Continuous Flooding.—The quantity of water used in the two field plots flooded in July, 1933, was 161,800 cubic feet. Since the plots totaled 1.02 acres, the water was used at the rate of 3.64 acre-feet. One plot was flooded ten days and the other thirteen; so the average quantity of water used per day was

approximately 4 acre-inches. More water was required at first than after the plots were thoroughly soaked.

In the second set of field plots, which was flooded in August, 1933, only part of the water was measured, but it was estimated that not less than 3 acre-feet were used.

COST OF FLOODING.—The cost of flooding will depend entirely on the cost of water, which in California ranges from 1 to 25 dollars per acre-foot. At the lower rates flooding would be practical, but at the higher rates it would be too expensive.

SUMMARY AND CONCLUSIONS.—Experiments in flooding the soil to control wireworms were tried in 1929 and 1930, but were discontinued because the results were not promising. The discovery, by other investigators, that soil temperature was an important factor in wireworm mortality caused by flooding led to the resumption of the flooding experiments in 1933 and 1934. These tests, which were performed under cage conditions and in field plots, were arranged in such a manner as to determine the effect of soil temperatures upon wireworm mortality, as well as the effect of the duration of the flooding period, the effect of plowing at various depths before flooding and the effect of continuous versus intermittent flooding.

The results of the tests led to the following conclusions: The mortality of wireworms from flooding depends largely on the temperature of the soil. Flooding, even for long periods, is relatively ineffective unless the soil temperature is 70° F. or above. Under these favorable conditions, 80 to 90 per cent of the wireworms are killed, the mortality increasing and the length of time required decreasing with rise in temperature. The majority of wireworms surviving the flooding operation are at a depth of 9 inches or more in the soil. Mortality is increased to a slight extent by plowing before flooding. Continuous flooding is more effective than intermittent flooding. About 4 acre-inches of water per day is required for flooding operations directed against wireworms.

In general it appears that the practicability of flooding to control wireworms depends on whether the soil temperatures will average 70° F. or above, and on the availability and the cost of water.—9-10-37.

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Studies on the Life History of the Pineapple Mealybug, *Pseudococcus brevipes* (Ckll.)[1]

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At the present time the pineapple mealybug, *Pseudococcus brevipes* (Ckll.) is considered the major insect pest of pineapple plants in Hawaii. Its economic importance is due primarily to its toxicogenic nature which causes the disease commonly known as "mealybug wilt" of pineapple plants. Tests conducted by Illingworth (1931) indicated that the mealybug transmitted wilt to pineapple plants. The evidences collected by Carter (1933a) from extensive field and careful laboratory experiments definitely established this mealybug as the vector of the disease.

Despite its economic importance, the life history of this mealybug has never been fully worked out. The general description given by Fullaway (1924) and supplemented by Illingworth (1926) is the only information of this nature available, although Swezey (1913) made some observations on the rate of reproduction of the female. In order to obtain more information concerning the mealybug, the following life history studies have been undertaken.

MEALYBUGS USED.—Carter (1933b)

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[2] The valuable suggestions and helpful criticisms made by Dr. Walter Carter during the course of this investigation are gratefully acknowledged.

referred to the existence of green spotting and non-green spotting strains of *P. brevipes*. He found that some colonies, notably gray bugs, produced green spots; while others, commonly pink, produced no green spots on pineapple plants. Suehiro (1936). After making comparative anatomical studies of these forms, discovered no morphological differences and concluded that they were one and the same species, thus confirming general opinion. However, life history experiments were conducted using both pink and gray forms.

Mealybugs of the pink form were taken from a stock colony which was originally started from mealybugs on two heavily infested second ratoon pineapple plants having a number of chlorotic spots but no green spots. The plants were obtained from a field on the island of Kauai where, though mealybug infestations on the plants were heavy, green spots were entirely absent. Life history observations were made on 20 crawlers from each of 10 gravid females taken from this stock colony.

Mealybugs of the gray form were taken from a colony previously started from 25 gravid gray females selected from a heavily green spotted pineapple plant found in a field at Wahiawa, Oahu. Colony transfers of the bugs unfailingly produced profuse green spots on pineapple leaves. Approximately 250 newly born crawlers from 10 females taken from the stock colony were used for the life history studies.

EXPERIMENTAL PROCEDURE.—The life history studies of the two forms of mealybugs were conducted under similar conditions in the laboratory. The experiments were set up at the beginning of February and ended during the latter part of June, 1933. The average temperature during this period was 74.4° F. with a maximum of 83.9° F. and a minimum of 61.3° F.

Ordinary test tubes, one-half inch in diameter and 6 inches long, securely stoppered with absorbent cotton plugs were used for caging the individual bugs. For food material, clean leaves from pineapple crowns selected from mealybug-free fields were used. These crowns were guarded against any chance mealybug infestation by keeping them in a large, bell-shaped jar securely covered with broadcloth. The leaves were first carefully cleansed prior to insertion into the tubes to obviate confusion of cuticular wax particles with the exuviae of the insects. A fresh leaf piece was substituted for the old one following each moult, a precaution later found unnecessary since it was discovered that a single leaf piece was capable of maintaining a whole colony without any noticeable deleterious effects on the development of the bugs. Where males developed, in the case of the gray form, the leaves upon which the cocoons were formed were left unchanged.

Gravid females of each of the two forms were taken from stock colonies. These females were carefully examined under a binocular microscope and all previously born crawlers found clinging to the body of the mothers were removed. The females were then singly confined in small vials. Crawlers, a day old, from these females were transferred with a camel's-hair brush into the test tube cages and observations were then made.

Daily examination of the young crawlers was made to ascertain the exact instance of moult of each individual bug. When moult had occurred, the cast skin was removed and the new instar larva was transferred to a new leaf piece. This process was in many cases greatly facilitated by the fact that most of the bugs did not commence feeding immediately after moulting. They usually remained unattached, either roaming about probably in search for more suitable feeding spots or staying sedentary for about a day before resumption of feeding.

LIFE HISTORIES OF THE PINK AND GRAY FORMS.—As a result of the daily handling of the test tube cages containing the individual bugs, only a comparatively small proportion of the original bugs ever came to maturity. A large number either died or were lost prior to the first moult. Nevertheless, sufficient numbers of both forms completed their life cycles to give adequate data for analysis.

The immature stages of the females of the two forms were alike in their metamorphic behavior. Three larval instars constituted this stage. Moult was the same as that described by MacGillivray (1921) for other species of the genus *Pseudococcus* where the new instar crawled out from an anterior slit in the old skin. No comparison of morphological

Table 1.—Life histories of the females of the pink and gray forms of *Pseudococcus brevipes* (Ckll.).

STAGE		PINK FORM Days	GRAY FORM Days
First Instar	Maximum	26	23
	Minimum	10	11
	Average	*13.96±0.14**	*14.36±0.16*
	No. of mealybugs:	135	101
Second Instar	Maximum	22	20
	Minimum	6	6
	Average	*9.79±0.20*	*8.90±0.22*
	No. of mealybugs:	113	101
Third Instar	Maximum	24	28
	Minimum	7	7
	Average	*10.28±0.19*	*11.34±0.28*
	No. of mealybugs:	102	91
Total of First, Second and Third Instars	Maximum	55	52
	Minimum	26	26
	Average	*33.89±0.32*	*34.57±0.40*
	No. of mealybugs:	102	91
Prelarvaposition period	Maximum	43	53
	Minimum	18	22
	Average	*26.58±0.41*	*25.83±0.69†*
	No. of mealybugs:	72	23
Larvaposition period	Maximum	44	42
	Minimum	1	18
	Average	*24.84±0.89*	*29.95±1.09*
	No. of mealybugs:	64	20
Postlarvaposition period	Maximum	32	17
	Minimum	1	1
	Average	*4.70±0.39*	*5.45±0.62*
	No. of mealybugs:	64	20
Total adult life	Maximum	80	72
	Minimum	31	48
	Average	*56.23±0.95*	*61.15±0.98†*
	No. of mealybugs:	64	20
Total life	Maximum	117	111
	Minimum	59	78
	Average	*90.00±1.03*	*94.55±1.07†*
	No. of mealybugs:	64	20

* Probable error of the average, in all cases.
† Recalculated time.

features can be made, as no examinations for them were undertaken.

The lengths of the different stadia varied greatly with individuals. Of the three instars, the first stadium of both forms was the longest and the second the shortest. However, individual cases existed where either the second stadium or the third or both was longer than the first.

The adult stages of the females of both forms were also similar in so far as the sequence of events was concerned. The stage was subdivided into three periods: the prelarvaposition period, the period prior to the production of the first crawler; the larvaposition period, the period during which crawlers were produced;

Table 2.—Life histories of the unmated females of the gray form of *Pseudococcus brevipes* (Ckll.).

Total adult life	Maximum	155*
	Minimum	48
	Average	*112.85±2.99*
	No. of mealybugs:	39
Total life	Maximum	189*
	Minimum	81
	Average	*148.13±3.05*
	No. of mealybugs:	39

* Female that was killed.

and the postlarvaposition period, the period after the emergence of the last crawlers to death of the female.

Apparently very little feeding is done during the last two periods of the adult life of gravid females, since it was observed that the females reproduced to maximum capacity even if kept detached from the leaves upon which they were feeding. At the time of death, the majority of them became very much reduced in size, inactive and shrivelled. The life histories of the two forms of *P. brevipes* are summarized in tables 1 and 2.

A marked difference in the modes of reproduction of the two forms was disclosed during the course of this work. As the development of the bugs progressed, it was discovered that no males differentiated from among the individuals of the pink form, while males developed from those of the gray form. The mode of reproduction of the gray form will be discussed later.

Table 3.—Daily rates of larvaposition of females of the pink and gray forms of *Pseudococcus brevipes* (Ckll.), 1933.

Date	Pink Form Female No. 1	2	3	4	5	Date	Gray Form Female No. 1	2	3	4	5
Mar. 21			16			Apr. 5			41		
22			22			6			35		
23			16			7			42	12	33
24			12			8	6		20	15	27
25	15		16			9	14	14	20	13	36
26	26		11			10	19	23	21	45	41
27	25		13			11	19	20	14	53	34
28	23	9	19	45	3	12	17	19	25	31	38
29	39	12	30	33	11	13	20	16	7	41	28
30	8	12	32	23	9	14	13	17	22	38	33
31	36	9	30	35	25	15	23	18	6	29	18
Apr. 1	19	15	30	28	14	16	30	12	11	40	38
2	18	7	22	26	34	17	22	9	9	30	31
3	18	9	31	28	24	18	12	14	3	28	22
4	11	11	14	26	12	19	20	15	4	25	24
5	15	15	20	26	21	20	23	12	1	23	27
6	17	5	11	21	14	21	21	9	0	31	23
7	6	21	5	20	20	22	10	8	1	23	27
8	12	11	1	16	17	23	4	7	1	15	21
9	14	10	1	21	11	24	1	3	0	6	15
10	15	11	4	16	12	25	1	3	1	3	8
11	9	6	10	14	12	26	0	2	0	6	10
12	3	9	3	15	18	27	0	3	0	4	3
13	2	4	2	6	5†	28	0	3	0*	6	7
14	3	0	1	6	5†	29	0	2		3	4
15	1	0	0	1	0	30	0	3		5	5
16	1	1	0	1	2†	May 1	0	1		3	5
17	0	0	0	2	1†	2	0	4		2	4
18	0	0	0	1	0	3	0	0		3	2
19	0	0	0	0	0	4	0	3		2	1
20	0	0	0	1	0	5	0	1		1	0
21	0	0	1	1	0*	6	0	2		2	1
22	0	0*	0	0		7	0	0		2	1
23	0		0	1		8	0	0		1	1
24	0*		1	1		9	0	0		3	0
25			0	0		10	0*	0		2	1
26			0	0*		11		0		4	0
27			0			12		0		3	0
28			0*			13		0		2	0
						14		0		1	1
						15		0		0	0
						16		0*		1	0
						17				0	0
						18				0*	0
						19					0*

* Female dead.
† Ovoid bodies.

The females of the pink form reproduced parthenogenetically. No males developed from the progenies of these females. The progenies were invariably pink, produced no green spots on the leaves upon which they fed, and eventually reproduced asexually. This method of reproduction was observed in all test cases of the pink form. Pink mealybugs collected from several grasses behaved similarly. Thus it may be definitely said that the pink form reproduces parthenogenetically, producing only females.

The females of both forms were viviparous as they produced crawlers instead of eggs. Occasionally ovoid bodies, possibly eggs which were prematurely laid and which remained unhatched for a few days, were encountered, but these incidents were rare. Dissection of several gravid females of both forms revealed the presence of fully developed crawlers, together with eggs at various stages of development. Daily rates of larvaposition of five pink and five gray females are presented in table 3.

The reproductive capacities of the two forms are summarized in table 4. It should be noted that in the calculation of the mean numbers of progenies produced by the females of the two forms, the ovoid bodies which were laid during larvaposition were included, while those which were dissected out of the females after death were excluded. The figures showed that the biotic potential of the gray form was much higher than that of the pink form.

Table 4.—A summary of the number of crawlers produced by the females of the pink and gray forms of *Pseudococcus brevipes* (Ckll.).

Form	No. of Females Involved	No. of Crawlers Produced		
		Maximum	Minimum	Average
Pink	64	692	4	234.08 ± 13.40
Gray	20	908	65	346.65 ± 9.39

MATING.—Inasmuch as male production was confined to the gray form, data on mating were obtained only in regard to this form. The breeding work was conducted under rather artificial conditions. Mating was performed by placing a male and an adult female into a small vial and plugging the vial with cotton to prevent their escape. After copulation, definitely determined by observation under a binocular microscope, the female was returned to its former cage. Transfers of the bugs to and from vials were made with the aid of a camel's-hair brush. It was observed that some males copulated several times at very short intervals of three to five minutes while others mated for long periods or even died clinging to the females in the copulatory position.

From the lot of matured females available, 24 were mated with males and the rest were left unmated. Out of the 24 mated females, 23 began reproducing, one being accidently killed. Of the remainder, only 20 females were successfully carried through to the end.

From the data on mating it was found that the length of the so-called prelarvaposition period was dependent on the time at which mating had taken place. A delay of mating naturally prolonged this period. For comparative purposes the actual lengths of the prelarvaposition period for the 23 females were recalculated by subtracting the length of time that had elapsed since the third moult until mating, from the actual length of the period, to obtain the true average for this period, as given in table 1. This recalculation was based on the assumption that mating occurred immediately after the third moult.

The summary for the adult stage of the life history of the unmated females has already been presented in table 2. The immature stages of these females were the same as for mated ones. From the data it may readily be seen that the length of the life of unmated females was considerably lengthened by the lack of fertilization by males. Some data obtained in a later experiment showed that mating could occur at any time after maturation of the female, resulting in the subsequent reproduction by the female. Thus, in nature, the chances of a female never being fertilized are probably very rare.

The abnormal life of the unmated females was made apparent by the fact that they became listless after a period of normal feeding. Many were seen roaming about over the leaf pieces. They were noticed to have become less active as time passed until, prior to death, most of them appeared sickly, weak and almost immobile. Dissection of such females showed only few or no ova.

On another occasion several crawlers, a day old, from six gravid gray females taken on pineapple plants from the field, were individually caged in small felt cages on pineapple leaves. From these progenies, four virgin females were selected from each parent female. Two of the four females from each parent female were mated with males, while the other two were kept unmated. All the 12 mated females began reproducing after 17 to 21 days following mating and all were dead within 40 days after the commencement of crawler production. On the other hand, none of the 12 unmated females reproduced. The majority of these females lived for a considerable time after the death of the mated females, but finally died without reproducing.

FIG. 1.—Male of *Pseudococcus brevipes* (Ckll.). Magnified 25 times.

Observations of several other cases, where individual crawlers from gray females were allowed to mature in single cages, showed that no crawler was produced by such females. From these results it may be safely said that the mode of reproduction of typically green spotting females of the gray form of the pineapple mealybug is sexual, producing both male and female progenies.

MALES.—As previously stated, male production was limited to the gray form only. The life history of the males of *P. brevipes* closely resembles that of *Pseudococcus citri* as given by Matheson (1907) and also by Myers (1932). The individual male moulted four times during development. Feeding was limited to the first instar and part of the second. The length of the first instar was practically the same as that of the females. Sex differentiation took place during the second instar. At this time the male larva became somewhat elongated in body and was seen crawling about sluggishly in search of a suitable place in which to spin its cocoon. The cocoon was loosely constructed of white, waxy filaments.

The second, third and fourth moults took place within the cocoon. The exuvia of each instar was shoved out toward the caudal end of the cocoon. The adult male did not emerge immediately after the fourth moult but remained quiescent for a few days within the cocoon. It was observed that in large colonies where male production was great, the males usually pupated in dry secluded places and in a mass.

The adult male is a delicate creature with only a pair of membranous wings. It has no externally developed mouthparts; so it does not feed during this stage. It is an ephemeral creature for, although unmated males were recorded as living for as long as five days, mated ones usually live for only a day or so after copulation.

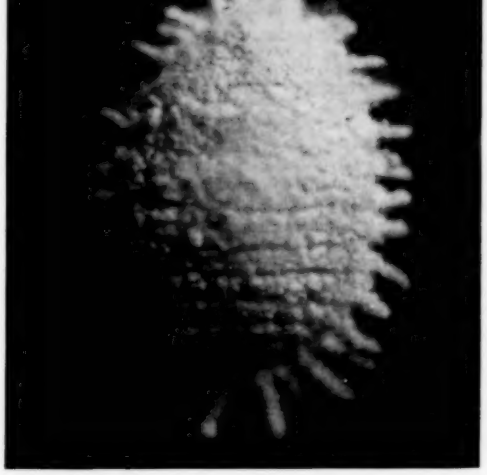

FIG. 2.—Female of *Pseudococcus brevipes* (Ckll.). Magnified about 25 times.

A comparison of the relative sizes of the

male and female mealybugs is illustrated in figs. 1 and 2, while a few of the male cocoons are shown in fig. 3.

A summary of the data for all of the males which had completed the various stages is presented in table 5. Out of the 166 bugs which had survived through the second instar, 65 were males and 101 females, thus giving a sex ratio of 0.61 for the lot.

While this sex ratio is slightly higher than the common ratio of equal males to females which has been recorded for other mealybugs, it cannot be taken as being the normal ratio, as the number of individuals involved is very small. Furthermore, observations of numerous other cases seem to indicate a great variability in the number of males produced by different females. It has also been observed that when mealybugs are transferred from one host plant to another, or even from one environment to another, a great number of males emerge.

FIG. 3.—Male cocoons of *Pseudococcus brevipes* (Ckll.). Magnified 25 times.

SUMMARY.—The life histories of the two forms (strains) of the pineapple mealybug, *Pseudococcus brevipes* (Ckll.), were studied under laboratory conditions. It was found that the pink form reproduced parthenogenetically, producing only females, while the gray form reproduced sexually, producing both males and females.

The females of both forms moulted three times before reaching maturity. The average number of progeny produced by 64 pink females was 234 and by 20 gray females was 347. The average length of life of the pink females was 90 days; of the mated gray females 95 days; and of 39 unmated gray females 148 days.

The males moulted four times before reaching the winged, adult stage. They fed only during the first and part of the second instar. They lived for an average length of 37 days. The winged adults spent an active life of about two days from the time of emerging from their cocoons until death.—7-12-37.

Table 5.—A summary of the life history of the males of the gray form of *Pseudococcus brevipes* (Ckll.).

STAGE	LENGTH IN DAYS			NO. OF MALES INVOLVED
	Maximum	Minimum	Average	
First instar	19	11	13.62±0.15	65
Second instar				
Period from first moult to cocoon formation	15	4	6.97±0.19	65
Period from cocoon formation to second moult	7	2	3.33±0.11	60
Total for this stage	19	7	10.13±0.19	60
Third Instar	7	2	3.43±0.10	54
Fourth Instar	8	2	5.44±0.20	50
Adult				
Period prior to emergence	5	1	2.61±0.10	49
Period from emergence to death	5	1	2.00±0.09	48
Total for this stage	7	2	4.65±0.10	48
Total life	*47*	*31*	*37.17±0.35*	*48*

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Toxicity of Fumigant-CO_2 Mixtures to the Red Flour Beetle[1]

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A review of the literature relating to the use of CO_2 in admixture with fumigants shows that moderate concentrations of this gas may have a marked effect on the respiratory system of insects, and that the quantity which is required to give the maximum insecticidal effect will vary with the kind of fumigant with which it is combined. Data are presented herewith which show the proper proportions in which CO_2 should be combined with methyl formate, ethylene oxide and methyl bromide. The results indicate that the stimulative effect produced by the CO_2 gas may be partly or wholly nullified if the percentage in the gaseous mixture is increased beyond the amount which is found to give the maximum increase in toxicity. Some of the earlier investigations are discussed briefly in the following paragraphs.

EARLIER INVESTIGATIONS.—Hazelhoff (1926, 1928) observed that the spiracular opening in insects is regulated normally by the percentage of CO_2 in the immediate neighborhood of the spiracles and suggested that the addition of small amounts of this gas may serve to increase the effectiveness of hydrocyanic acid gas or other respiratory insecticides. Later investigations by Campbell (unpublished data; see Cotton 1932, p. 1099) and Cotton (1932), however, have shown that the insecticidal action of HCN is not increased by the addition of CO_2. These results are confirned by Pratt, *et al.* (1933), who observed that the addition of 1 per cent and 99.8 per cent of CO_2 actually decreased the toxicity of 0.2 per cent HCN to the convergent ladybeetle *Hippodamia convergens* Guer. No information is given regarding the possible effects of intermediate percentages of CO_2.

McGovran (1932) observed that a concentration of 15 per cent of CO_2 may increase the rate of tracheal ventilation of the grasshopper, *Arphia sulphurea* F., as much as 20 times the normal, or slightly more than 1900 per cent. The effect of 1 per cent of CO_2 was to increase the average rate about 5 per cent. No fumigants were used in admixture with the 1 per cent and 15 per cent CO_2-air mixtures. Kitchel & Hoskins (1935) also studied the effect of various concentrations of CO_2 on the rate of respiratory ventilation in the Hawaiian cockroach, *Nyctobora noctivaga* Rehn, and concluded that all of the lower concentrations of CO_2 cause an immediate increase in the rate of ventilation and that the speed of the response is dependent upon the concentration. With 5, 10 and 15 per cent of CO_2, the maximum rates of ventilation are approximately 3, 5 and 6 times the normal rate in air. With 20 and 30 per cent mixtures, a tremendous initial increase in ventilation is followed by an almost immediate decrease, particularly with the latter concentration. Mixtures containing 50 per cent of CO_2 gave very variable results. Undiluted CO_2 caused an

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immediate decline in ventilation and no evidence of an initial acceleration was found. In summarizing, the authors state "The influence of CO_2 is twofold. It comprises an initial stimulus whose intensity varies directly with the concentration, and an anesthetic effect which becomes noticeable after a period whose duration varies inversely with the concentration."

In determining the loss of water from the larval forms of the yellow mealworm, *Tenebrio molitor* L., the webbing clothes moth, *Tineola biselliella* (Hum.), and the oriental rat flea, *Xenopsylla cheopsis* (Rothsch.), Mellanby (1934) found that he could keep the spiracles of the insects open permanently by adding 5 per cent of CO_2 to the atmosphere. It was also observed that the same effect could be produced by reducing the oxygen supply to less than 1 per cent.

Willis (1925) states that there may be a chemical explanation of the effects of CO_2 on insects. The breathing movements of grasshoppers, *Melanoplus differentialis* (Thos.) and *M. femur-rubrum* (Deg.), may be brought about by a stimulation of the nerve ganglia in the abdominal segments, either as a result of an increase in hydrogen ion concentration, or pH, of the blood when the CO_2 goes into solution, or by the CO_2 acting in an undissociated state. Willis believes that the effect is similar to that produced by this gas in stimulating the respiratory center in mammals. In discussing the mode of action of CO_2, Stahn (1928) considers three possibilities: (1) that the effective stimulus is the pH in the nerve center, (2) that the gas in the tracheal endings is the specific stimulus or (3) that the gas acts on some peripheral receptor. Most work, however, indicates that the pH in the region of the nerve center probably plays the greatest part in bringing about the stimulation of the respiratory mechanism.

Cotton & Young (1929) published the first account of the use of CO_2 in combination with fumigants. The results obtained by these investigators in combining CO_2 with ethylene dichloride, methyl chloroacetate, carbon disulphide and chloropicrin indicate that a dosage of CO_2 between 165 and 330 mg. per liter would, from the standpoint of economy and efficiency, be the most satisfactory for fumigation purposes. These dosages are equivalent to approximately 10 and 20 pounds, respectively, per 1,000 cubic feet (or 9 and 18 per cent, by volume).

In a more recent publication, Cotton (1932) states that the quantity of CO_2 needed to give the maximum insecticidal effect varies with the kind of fumigant used. He ascertained that the maximum effect with carbon disulphide (against the confused flour beetle) is obtained in an atmosphere containing approximately 15 pounds of CO_2 per 1000 cubic feet of space. The greatest increase in toxicity of ethylene oxide and chloropicrin was obtained with 30 and 37 pounds, respectively, per 1000 cubic feet. These tests, however, were conducted under vacuum fumigation conditions, and the results obtained may not necessarily coincide with the results of experiments carried out under atmospheric pressure conditions.

METHOD.—Adults of the red flour beetles, *Tribolium castaneum* (Hbst.), were used in all the experiments reported in this paper. The insects were reared on whole corn meal at a constant temperature of 27 degrees C. and a relative humidity of 65 to 70 per cent. Twenty-five individuals were used in each test, and eight duplicate experiments were performed for each set of conditions. Two hundred insects were, therefore, employed for determining the average mortality with a given concentration or a given time exposure of the fumigants tested. The beetles were selected at random from a homogeneous population.

No beetles older than 4 to 6 weeks were used in the experimental work, although numerous untreated lots of insects showed that there was no natural mortality of the young adults. Each set of experiments was accompanied by two check samples of 25 insects each. However, none of these untreated beetles died during the time they were held for observation, further indicating that the natural mortality of the young adults of this species is very low.

The insects were placed, after treatment, on whole corn meal in specimen vials and examined on alternate days for a period of a week or more. The criterion of death was the inability of the insect to walk on a flat surface, as experience showed that, in general, those which could not walk within two or three days

after treatment nearly always failed to recover.

The apparatus (Jones 1933) employed for conducting the toxicity experiments is shown in fig. 1 and consists of eight *Pyrex* fumigation flasks closed with ground glass plates at *B* to make an air-tight joint. The ground glass male fittings on the flasks are all interchangeable with the female ground joint shown at *C*. The fumigants (methyl formate and ethylene oxide) are placed in the small 25 cc. flasks shown at *D*. The higher vapor pressure of methyl bromide necessitates a stronger container than the glass flasks, and this chemical was stored in the metal cylinder at *K*.

The use of this apparatus permits the vapors of volatile fumigants, instead of the liquid substance, to be introduced into the partially evacuated five-liter flasks, the amounts being measured by means of the mercury manometer. The fall of the mercury in the manometer is a direct measure of the concentration of the gases in the fumigation flasks. This is based on the fact that one mol of a compound occupies 22.4 liters at S.T.P. Fractional parts, expressed as milligrams per liter or per cent by volume, may therefore be conveniently and accurately measured. It is not necessary to evacuate the apparatus completely, as the percentage of the gases in the flask is calculated on the basis of the prevailing barometric pressure at the time the tests are conducted. Evacuation until the mercury in the manometer has reached a

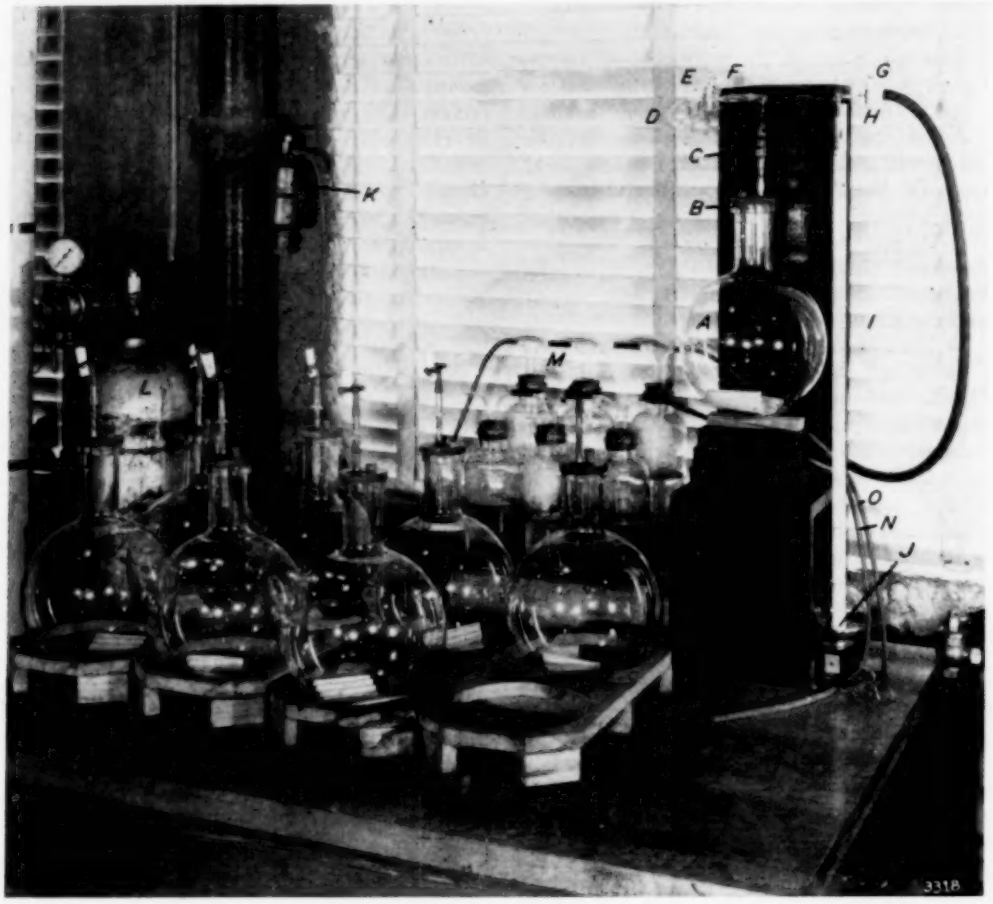

FIG. 1.—Apparatus employed for determining the toxicity of fumigant-CO_2 mixtures to *Tribolium castaneum*.

height of about 625 mm. also results in a considerable saving of time, and this procedure was followed except where high concentrations of CO_2 were required. Air is then admitted until the mixture within the flask is reduced to atmospheric pressure.

ANALYSIS OF DATA.—Insecticidal data are usually expressed by an asymmetrical sigmoid or S-shaped curve, in which the percentage mortality is plotted against the concentration of the toxic agent. Such curves, however, usually flatten to an asymtote in the range of concentrations which produce a 100 per cent kill of the insects, and it is frequently difficult to compare the relative toxicity of fumigants at, or near, the point of complete mortality. The inherent variability among individuals of a population in their susceptibility is considered to be responsible for the S-shaped character of the curve.

Bliss (1935) minimizes the above disadvantages by transforming the per cent mortality and the concentration of toxic agent to units which may be plotted as straight lines on ordinary cross-section paper. These units are designated as probits, or probability units, and permit the observed 0.1 per cent kill to equal 1.9098, 50.0 per cent kill to equal 5.0000 and 99.99 per cent kill to equal 8.7190. The intermediate values are calculated in a symmetrical manner. While no provision is made for a complete kill of all the insects, except at an infinite concentration of the toxic agent, the probit-log scale has the advantages offered by a straight line and is used in the graphical presentation of the results reported herein. The toxicity lines in the graphs are fitted by visual inspection to the experimentally determined points, rather than by mathematical location of the line of best fit.

RESULTS.—The results are discussed under the following subheads: (1) toxicity of methyl formate, ethylene oxide and methyl bromide, (2) toxicity of mixtures of methyl formate and CO_2, (3) toxicity of mixtures of ethylene oxide and CO_2 and (4) toxicity of mixtures of methyl bromide and CO_2.

METHYL FORMATE, ETHYLENE OXIDE AND METHYL BROMIDE.—In table 1 and fig. 2 are shown the data obtained on the toxicity of these fumigants, in air, to the adults of *T. castaneum*. The logarithms of the concentrations of the respective fumigants are shown in the table, together with the probit value for each percentage mortality. Probit values corresponding with 0 per cent and 100 per cent kill are not included, because, as stated previously, this arrangement of the data does not allow for the possibility of zero mortality or complete mortality, except at an infinitely low or infinitely high concentration of the fumigant.

Table 1.—Comparative toxicity of methyl formate, ethylene oxide and methyl bromide to adults of *Tribolium castaneum*. Length of exposure, five hours.

CONCENTRATION, MG./LITER	PERCENTAGE MORTALITY		
	Methyl Formate	Ethylene Oxide	Methyl Bromide
5.00 (0.6990)*			0.0
6.25 (0.7959)			57.5† (5.1891)‡
7.50 (0.8751)			93.5 (6.5141)
8.75 (0.9420)			100.0
10.00 (1.0000)		0.0	
12.50 (1.0969)		30.5 (4.4899)	
15.00 (1.1761)	0.0	80.5 (5.8496)	
17.50 (1.2430)	44.0 (4.8496)	100.0	
20.00 (1.3010)	81.5 (5.8965)		
22.50 (1.3522)	98.0 (7.0537)		
25.00 (1.3979)	100.0		

* Logarithms of the concentrations.
† Average per cent mortality of eight duplicate tests.
‡ Per cent mortality in terms of probits.

The results in the table show that methyl bromide is more toxic than methyl formate and ethylene oxide to the adults of *T. castaneum*. The concentrations of these fumigants required to kill all of the beetles in 5 hours at a temperature of 27 degrees C. are as follows: (1) methyl formate, 25.0 mg. per liter, (2) ethylene oxide, 17.5 mg. per liter and (3) methyl

bromide, 8.75 mg. per liter. The relative toxicity of methyl formate, ethylene oxide and methyl bromide may therefore be expressed, assuming the toxic action of methyl bromide as unity, by the ratio 2.86:2.00:1.00. Thus, it will be seen that twice as much ethylene oxide, or nearly three times as much methyl formate, are required to produce results equal to methyl bromide under similar conditions.

cent is the standard of mortality. When higher or lower standards are used, the individual variation in resistance of the insects to poisons necessitates the use of large numbers of insects to correct for this variation.

In the preceding experiments, the writer determined the concentrations of methyl formate, ethylene oxide and methyl bromide, which are required to

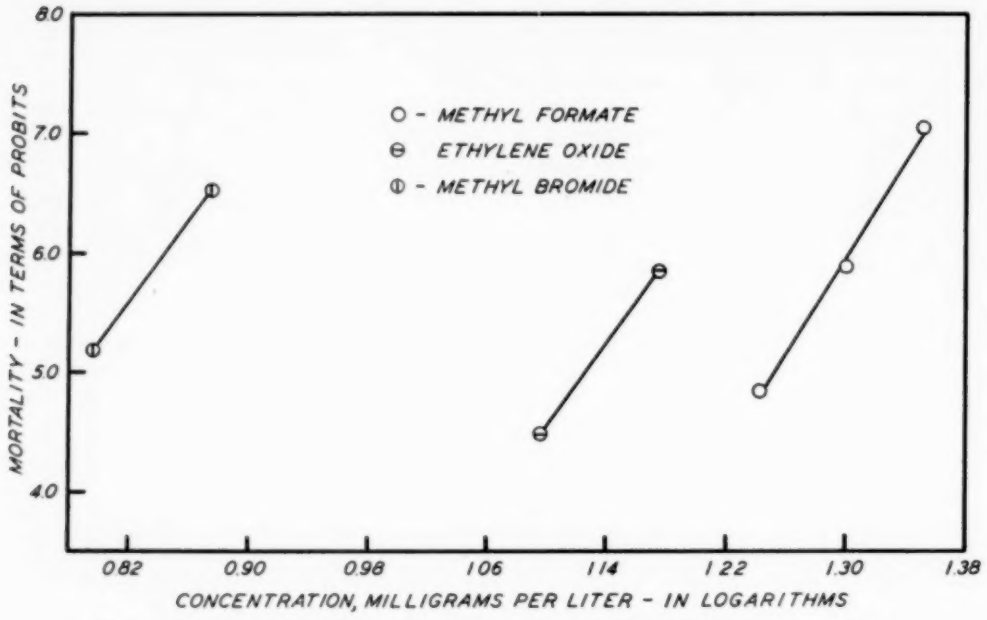

FIG. 2.—Toxicity of methyl formate, ethylene oxide and methyl bromide to adults of *Tribolium castaneum*.

In table 2 are shown the concentrations of methyl formate, ethylene oxide and methyl bromide required to kill approximately 50 per cent and 100 per cent of the beetles in 5 hours. The 50 per cent points were determined by interpolation, and are included because past experience has shown that the most nearly accurate comparisons can usually be made when 50 per

Table 2.—Concentrations of methyl formate, ethylene oxide and methyl bromide required to kill 50 per cent and 100 per cent of *Tribolium castaneum* in five hours.

FUMIGANT	CONCENTRATION, IN MG. PER LITER, REQUIRED TO KILL 50%	100%
Methyl Formate	17.81	25.00
Ethylene Oxide	13.44	17.50
Methyl Bromide	6.13	8.75

kill 100 per cent of the adults of *T. castaneum* in a period of 5 hours. Following this, tests were conducted in which the concentrations found above to be required to kill all of the insects in 5 hours were permitted to be the constant factor, and the exposure period was varied from the interval of time which gave 100 per cent kill (5 hours) to that which produced no mortality. Therefore, it will be noted in some of the tables of data, 3, 4, 5 and 6, that the concentrations of the fumigants are constant, whereas the time of the exposure varies from one-fourth hour to 5 hours, and the percentage of CO_2 from 1 per cent to 99.8 per cent.

MIXTURES OF METHYL FORMATE AND CO_2.—The results obtained when CO_2, in various percentages, is added to atmospheres containing 25.0 mg. of methyl

formate per liter are presented in table 3 and fig. 3. Table 1 shows that the above concentration of methyl formate is just sufficient to produce a 100 per cent mortality with an exposure of 5 hours. The logarithms of the time of exposure are shown in the table, together with the probit values for the respective mortalities.

all of the insects to $2\frac{1}{2}$, 2, $1\frac{1}{2}$ and $\frac{3}{4}$ hours, respectively.

The data in table 3 indicate, therefore, that the maximum efficiency of methyl formate (when used at the rate of 25.0 mg. per liter) is attained upon the addition of 40 per cent of CO_2. Percentages of CO_2 higher than 40 per cent apparently impart no additional increase in the toxicity

Table 3.—Toxicity of mixtures of methyl formate and CO_2 to adults of *Tribolium castaneum*.

Hours Exposed	Average Per Cent Mortality: Methyl Formate (25.0 mg./liter) Plus CO_2 as Follows								
	0%	1%	5%	10%	20%	40%	60%	80%	99.8%
$\frac{1}{4}$ 1.3979			6.0 —	20.0 4.158	28.0 4.417	32.0 4.532	34.0 4.588	24.0 4.294	30.0 4.476
$\frac{1}{2}$ 1.6990				63.0 5.332	90.0 6.282	98.0 7.054	98.5 7.170	99.0 7.326	98.5 7.170
$\frac{3}{4}$ 1.8751			50.0 5.000	86.0 6.080	95.0 6.645	100.0 —	100.0 —	100.0 —	100.0 —
1 0.0000	0.0 —	0.0 —	65.0 5.385		98.0 7.054				
$1\frac{1}{2}$ 0.1761		21.5 4.211	80.0 5.842	98.5 7.170	100.0 —				
2 0.3010	30.5 4.490	45.0 4.874	90.5 6.311	100.0 —					
$2\frac{1}{2}$ 0.3979		65.0 5.385	100.0 —						
3 0.4771	70.0 5.524	88.5 6.200							
$3\frac{1}{2}$ 0.5441		100.0 —							
4 0.6021	92.5 6.440								
$4\frac{1}{2}$ 0.6532	98.0 7.054								
5 0.6990	100.0 —								

The results show that CO_2 has a marked effect on the toxicity of methyl formate to the adults of *T. castaneum*. When 1 per cent of CO_2 is added to atmospheres containing the above amount of methyl formate, the period of exposure required to kill all of the insects is decreased to $3\frac{1}{2}$ hours, as compared with 5 hours when no CO_2 is present in the gaseous mixture. The effect is even more pronounced when the percentage of CO_2 is further increased. The addition of 5, 10, 20 and 40 per cent of CO_2 reduces the time required to kill

of this chemical to *T. castaneum*. In general, the results obtained when 60, 80 and 99.8 per cent of CO_2 are admixed with methyl formate seem to be in close agreement with those obtained from the addition of 40 per cent of CO_2. Fig. 3 shows that the mortality points lie on or close to the straight lines and that all of the lines are straight with the exception of the toxicity line for methyl formate plus 20 per cent of CO_2. This line starts in the expected manner, but breaks fairly sharply in the range of 95 to 98 per cent

mortality. An explanation of the probable cause of this discrepancy is not indicated by the available data.

MIXTURES OF ETHYLENE OXIDE AND CO_2.—In table 4 and fig. 4 are shown the data obtained when the various percentages of CO_2 are admixed with atmospheres containing 17.5 mg. of ethylene oxide per liter. These results indicate that admixing CO_2 with ethylene oxide produces a stimulative effect on *T. castaneum* similar to that observed with methyl formate, although to a slightly less extent.

It is interesting to note that whereas the addition of 1 per cent of CO_2 is accompanied by a definite increase in the toxicity of methyl formate, no effect is observed when this amount of CO_2 is admixed with ethylene oxide. When 5 per cent of CO_2 is admixed with ethylene oxide, however, the length of time necessary to kill 100 per cent is reduced to 3 hours. A further reduction in time to $1\frac{1}{2}$ hours is observed when the concentration of CO_2 is increased to 10 per cent. All of the insects are killed in $\frac{3}{4}$ of an hour when CO_2 is added at the rate of 20, 40, 60, 80 and 99.8 per cent. The data also show that mixtures containing 80 and 99.8 per cent of CO_2 appear somewhat less toxic in their action than those which contain 60 per cent of CO_2. The average mortality obtained with mixtures of ethylene oxide plus 60 per cent of CO_2 was 98.5 per cent, whereas the addition of 80 and 99.8 per cent of CO_2 resulted in an average mortality, in 45 minutes, of 95.0 per cent and 93.5 per cent, respectively. A statistical analysis of the data would be necessary to determine whether these differences are significant, or due merely to random sampling from a homogeneous population. The closely agreeing results on the toxicity of ethylene oxide plus 20, 40, 60, 80 and 99.8 per cent of CO_2, however, indicate no great differences in the effectiveness of the five mixtures.

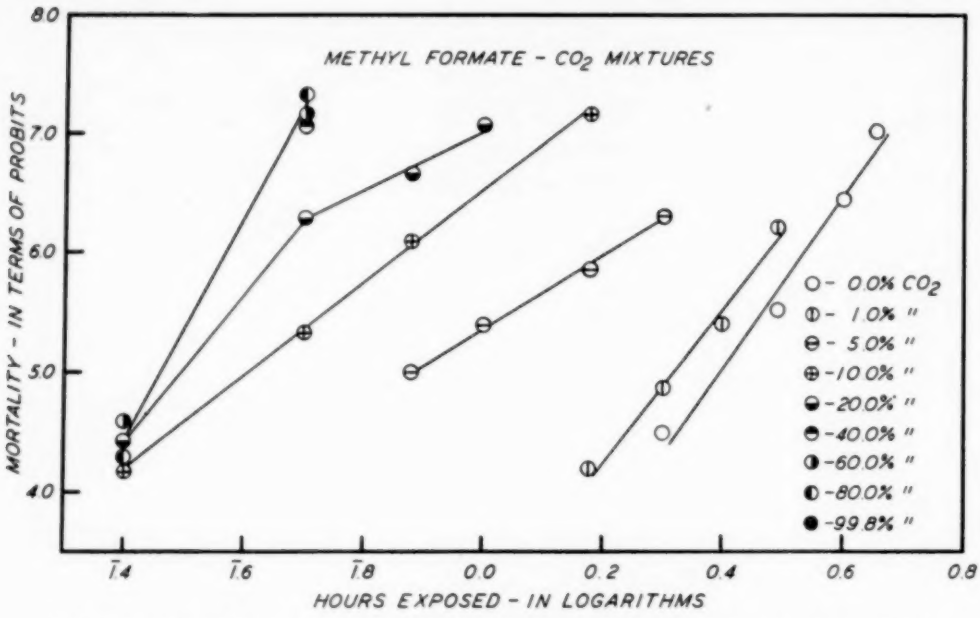

FIG. 3.—Toxicity of atmospheres of methyl formate (25.0 mg. per liter), plus various percentages of CO_2, to adults of *Tribolium castaneum*.

MIXTURES OF METHYL BROMIDE AND CO_2.—The results obtained when CO_2 is admixed with methyl bromide are shown in table 5 and fig. 5, and bring out several interesting points with respect to the role which this gas may play in stimulating insect respiration and increasing the toxicity of fumigants.

It should be noted, in the first place, that the addition of CO_2 apparently does not have as great an effect in increasing the toxicity of methyl bromide as is observed in the case of methyl formate and ethylene oxide, and, in the second place, that there is a definite increase in the

Table 4.—Toxicity of mixtures of ethylene oxide and CO_2 to adults of *Tribolium castaneum*.

Hours Exposed	Average Per Cent Mortality Ethylene Oxide (17.5 mg./liter) Plus CO_2 as Follows								
	0%	1%	5%	10%	20%	40%	60%	80%	99.8%
$\frac{1}{2}$				0.0	10.0	10.0	38.0	8.0	12.0
$\bar{1}$.3979				—	3.714	3.714	4.695	3.595	3.825
$\frac{1}{2}$			0.0	31.5	96.5	96.0	98.5	95.0	93.5
$\bar{1}$.6990			—	4.518	6.812	6.751	7.170	6.645	6.514
$\frac{3}{4}$				65.0	100.0	100.0	100.0	100.0	100.0
$\bar{1}$.8751				5.385	—	—	—	—	—
1	0.0	0.0	20.0	90.0					
0.0000	—	—	4.158	6.282					
$1\frac{1}{2}$			50.5	100.0					
0.1761			5.013	—					
2	20.5	25.0	80.0						
0.3010	4.176	4.326	5.842						
$2\frac{1}{2}$			94.5						
0.3979			6.598						
3	78.5	72.5	100.0						
0.4771	5.789	5.598	—						
4	95.5	96.5							
0.6021	6.695	6.812							
$4\frac{1}{2}$	99.0	99.0							
0.6532	7.326	7.326							
5	100.0	100.0							
0.6990	—	—							

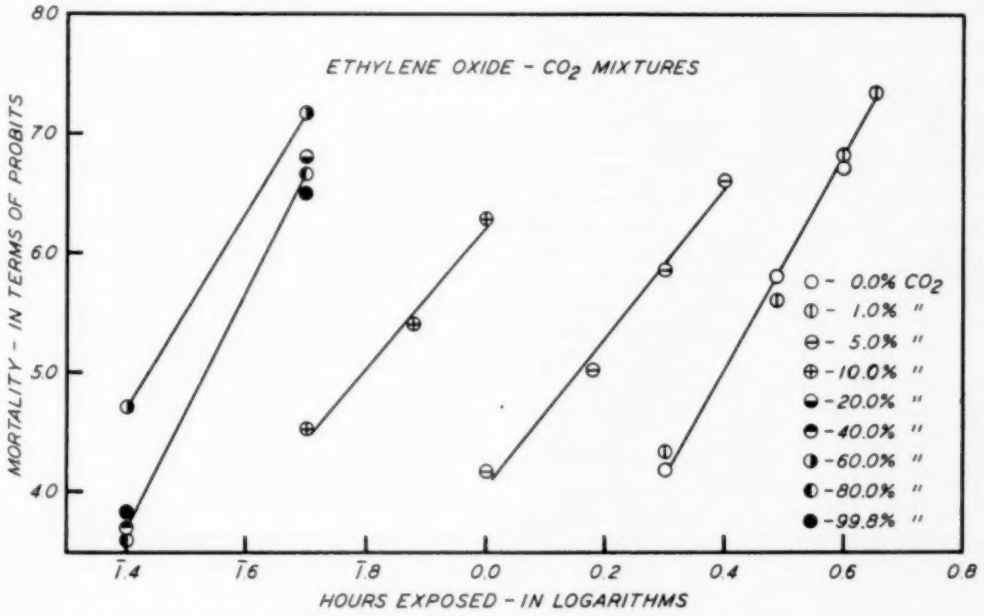

FIG. 4.—Toxicity of atmospheres of ethylene oxide (17.5 mg. per liter), plus various percentages of CO_2, to adults of *Tribolium castaneum*.

Table 5.—Toxicity of mixtures of methyl bromide and CO_2 to adults of *Tribolium castaneum*.

Hours Exposed	Average Per Cent Mortality Methyl Bromide (8.75 mg./liter) Plus CO_2 as Follows								
	0 %	1%	5%	10%	29%	40%	60%	80%	99.8%
1 0.0000					0.0 —	0.0 —			
1½ 0.1761			0.0 —	0.0 —	28.5 4.432	23.0 4.261	0.0 —	0.0 —	
2 0.3010		0.0 —	11.5 3.800	46.0 4.900	74.0 5.643	60.0 5.253	17.0 4.046	20.0 4.158	0.0 —
2½ 0.3979			60.0 5.253	78.5 5.789	96.5 6.812	84.5 6.015	65.0 5.385	50.0 5.000	
3 0.4771	0.0 —	46.0 4.900	84.0 5.995	100.0 —	100.0 —	100.0 —	93.5 6.514	86.0 6.080	43.5 4.836
3½ 0.5441	23.5 4.278	63.0 5.332	95.0 6.645				100.0 —	96.0 6.751	58.0 5.202
4 0.6021	72.5 5.598	90.0 6.282	100.0 —					100.0 —	92.0 6.405
4½ 0.6532	96.0 6.751	100.0 —							100.0 —
5 0.6990	100.0 —								

toxicity of the methyl bromide, as the CO_2 concentration is increased up to 20 per cent, after which there is a correspondingly definite decrease in the toxicity of the gaseous mixture. In comparing these data, it will be seen that atmospheres containing 8.75 mg. of methyl bromide per liter plus 1 per cent and 99.8 per cent of CO_2 have approximately the same degree of toxicity to adults of *T. castaneum*,

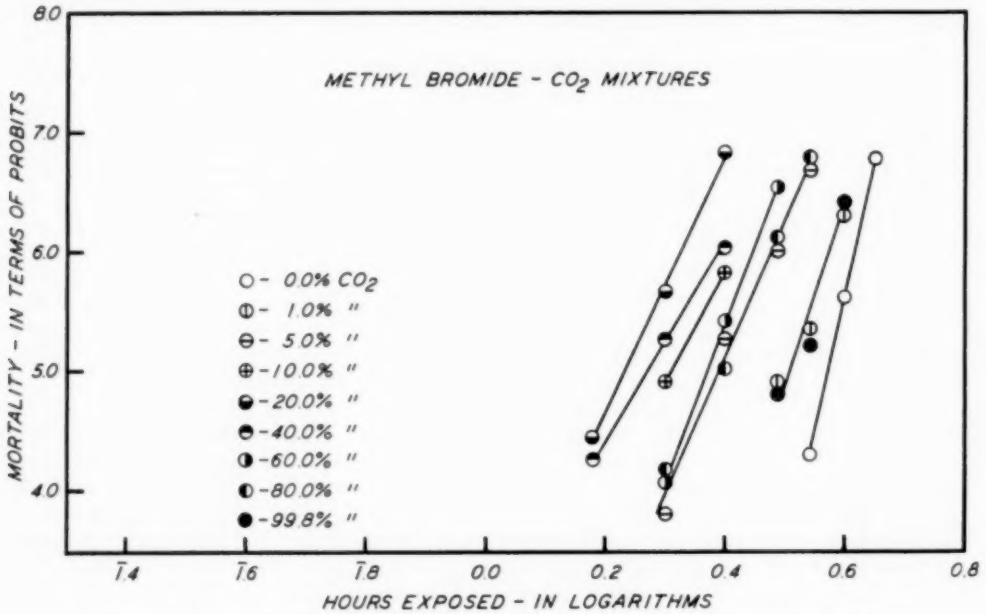

FIG. 5.—Toxicity of atmospheres of methyl bromide (8.75 mg. per liter), plus various percentages of CO_2, to adults of *Tribolium castaneum*.

and are only slightly more toxic than the above concentration of methyl bromide without the addition of the CO_2. Both of these mixtures require 4½ hours to kill all of the insects, as compared with an exposure period of 5 hours when no CO_2 is incorporated into the gaseous mixture. It is also apparent that methyl bromide plus 80 per cent of CO_2 is no more toxic than methyl bromide plus 5 per cent of CO_2, three fumigant-CO_2 mixtures when this standard is used as the basis of comparison. The table also shows that, from a practical standpoint, the most effective mixtures of methyl formate, ethylene oxide and methyl bromide with CO_2 are those containing 40, 20 and 10 per cent of CO_2, respectively. As the experiments reported herein were conducted in empty glass flasks, the above proportions of

Table 6.—Length of time required to kill 50 per cent and 100 per cent of *Tribolium castaneum* with selected concentrations of methyl formate, ethylene oxide and methyl bromide, plus various percentages of CO_2.

Percentage of CO_2 in Gaseous Mixture	Time Required (in Hours and Minutes) to Kill					
	Methyl Formate 25.0 mg./liter		Ethylene Oxide 17.5 mg./liter		Methyl Bromide 8.75 mg./liter	
	50%	100%	50%	100%	50%	100%
0.0	2:30	5:00	2:30	5:00	3:40	5:00
1.0	2:05	3:30	2:30	5:00	3:10	4:30
5.0	45	2:30	1:22	3:00	2:25	4:00
10.0	25	2:00	36	1:30	2:05	3:00
20.0	19	1:30	22	45	1:40	3:00
40.0	17	45	22	45	1:50	3:00
60.0	17	45	17	45	2:20	3:30
80.0	17	45	22	45	2:25	4:00
99.8	17	45	22	45	3:10	4:30

an exposure period of 4 hours being required to kill 100 per cent of the beetles with each concentration.

The data indicate further that a concentration of between 10 per cent and 40 per cent of CO_2 produces the maximum stimulative effect when used in admixture with 8.75 mg. of methyl bromide per liter. Mixtures containing 10, 20 and 40 per cent of CO_2 are equally effective in giving a complete kill of the insects with an exposure period of 3 hours, but the atmospheres with 20 per cent of CO_2 are somewhat more toxic in the lower range of mortalities.

The data tabulated in tables 3, 4 and 5 are summarized in table 6. This table shows at a glance the length of time required to kill 50 per cent, as well as 100 per cent, of the adults of *T. castaneum* with atmospheres containing various percentages of CO_2 in admixture with methyl formate, ethylene oxide and methyl bromide. While the 50 per cent points were determined by interpolation, they are sufficiently close for comparative purposes and show the relative effects of the fumigant and CO_2 may have to be altered somewhat under practical fumigating conditions to offset the effects of adsorption, absorption, lower temperature, excessive humidity, etc.

DISCUSSION.—An adequate explanation is not available at this time which will account for the differences observed above, but it is obvious that the addition of certain percentages of CO_2 results in a decided increase in the toxicity of the fumigants, especially methyl formate and ethylene oxide. The data also show that the toxicity of the gaseous mixture may be materially lowered if the CO_2 is added in excess. No mention is made in the literature of an adverse reaction occurring when abnormally high concentrations of CO_2 are combined with fumigants.

The respiratory centers of insects are stimulated not only by an excess of CO_2, but also by a lack of atmospheric oxygen. The specific stimulus which brings about an increase in respiration appears, therefore, to be the degree of acidity in the nerve centers. An increase in the pH of the body fluids of an insect may be

brought about either by increasing the CO_2 tension in the atmosphere, or by the accumulation of acid products in the body during a period when the normal metabolism is suspended, or retarded, because of insufficient oxygen. These factors are no doubt intimately correlated with the phenomena observed in this investigation, but it is difficult, without further detailed work, to ascribe to each the particular role it plays in contributing to the ultimate death of the insect.

Stahn (1928) observed that concentrations of 0.2 to 3.0 per cent of CO_2 are sufficient to stimulate the secondary respiratory center (located in the prothorax) of *Dixippus morosus*, whereas the primary respiratory centers (found in the segmental ganglia) respond to 12 per cent to 15 per cent of CO_2. No data are given on the physiological effects attending the exposure of insects to high concentrations of CO_2, but it is of considerable interest to note that the greatest increase in the toxicity of methyl formate, ethylene oxide and methyl bromide occurred when 5 to 20 per cent of CO_2 was added to the gaseous mixture. Perhaps the percentage of CO_2 required to stimulate the segmental ganglia may vary between certain limits, depending upon other external factors, such as the kind and concentration of the principal toxic agent.

Wigglesworth (1931) points out that while terrestrial insects take in most of the oxygen by way of the tracheal system, experimental evidence indicates that as much as 25 per cent of the normal production of CO_2 may be eliminated directly through the integument. In other words, the diffusion rate through the cuticle is considerably higher for CO_2 than for oxygen (the ratio is about 35 to 1). It is likely, therefore, that when insects are subjected to atmospheres containing abnormally high concentrations of CO_2, such as prepared in this investigation, a considerable part of the CO_2 may enter through the integument. No information is available to indicate the manner in which methyl formate, ethylene oxide and methyl bromide gain entrance to the body of the insect.

SUMMARY.—Data are given on the toxicity of methyl formate, ethylene oxide and methyl bromide to the adults of the red flour beetle, *Tribolium castaneum* (Hbst.).

Experiments were also conducted in which CO_2 in the proportions of 1, 5, 10, 20, 40, 60, 80 and 99.8 per cent was admixed with methyl formate, ethylene oxide and methyl bromide, and evidence is presented to show that the toxicity of these fumigants may be markedly increased by the addition of certain percentages of this gas.

The results obtained indicate that the stimulative effect produced by CO_2 is considerably more pronounced with methyl formate and ethylene oxide than with methyl bromide. Data are also included which show that the use of concentrations of CO_2 in excess of the quantity which is required to produce the maximum increase in insecticidal efficiency may result in a material lowering of the toxicity of the gaseous mixtures.

The maximum insecticidal effect of methyl formate, ethylene oxide and methyl bromide is obtained with concentrations of approximately 40, 20 and 10 per cent of CO_2, respectively, and the addition of CO_2 in excess of these percentages may either impart no further increase in toxicity to the mixture, or may actually decrease the effectiveness of the gaseous mixture.—3-16-38.

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The Relative Efficiency of Certain Fluorine and Arsenic Insecticides Against the Cowpea Curculio[1]

F. S. ARANT,[2] *Alabama Polytechnic Institute, Auburn*

Laboratory experiments to determine the effectiveness of certain insecticides against the cowpea curculio, *Chalcodermus aeneus* Boh., were conducted intermittently from 1930 to 1935 at the Alabama Agricultural Experiment Station. Attempts at feeding the insect measurable amounts of the materials were unsuccessful. Although the cowpea curculio has chewing mouthparts on the end of its snout, it could not be fed insecticides in leaf sandwiches or baits because the snout is usually inserted into plant tissues where the food is obtained. Other experiments during the period 1930–33 were only partly successful. The effect from certain arsenic and fluorine compounds was somewhat variable and inconclusive in two series of cage tests. Sodium fluosilicate appeared more effective as a stomach poison than eight other materials. Pyrethrum, talc and 4-amino-di-phenyl were 100 per cent inefficient. In a third series of tests, conducted according to a procedure used successfully against *Diabrotica duodecimpunctata* (F.) (Richardson & Glover 1932), the curculios were killed so slowly that the method was finally discarded. Hence, this paper contains a detailed account of only those experiments conducted during the period 1934–35. Results of field experiments with most of the insecticides studied in the laboratory are reported elsewhere (Arant 1938).

PROCEDURE.—In preliminary toxicity tests, conducted in 1934, the insects were confined in Petri dishes containing a film of insecticidal dust. The beetles crawled in the powdered insecticide and usually obtained a lethal dose. In these preliminary tests and also in one group of experiments conducted during 1935, the insects remained in continuous contact with the insecticide until dead. In addition to the continuous exposure tests, extensive experiments were conducted in 1935 in which the insects were exposed to the insecticides for periods of six, eight and ten hours, after which they were removed from the Petri dishes and placed on food. Twenty-five beetles were used in each test and four tests were conducted for each insecticide at each of the three exposures. The tests for all insecticides, at a given exposure, were conducted simultaneously at room temperature and checks with and without food were provided. Observations to determine the mortality were made at four-hour intervals.

It is difficult to know just when to consider any insect dead, but it was especially difficult to determine when a cowpea curculio was dead, due to the insect's habit of sulling or feigning death when disturbed. It was found, however, that the insect has a rather characteristic sulling posture and that a sulling beetle would almost invariably move if prodded between the coxae with a hard pointed object such as a dull dissecting needle. The insect was considered dead when it would no longer respond to the pressure of a needle. Each insect recorded as dead was placed in a marked container and observed, first without being disturbed and

[1] Contribution from the Department of Zoology-Entomology, Alabama Polytechnic Institute, Auburn. This report is taken from a doctorate thesis submitted to the graduate faculty of Iowa State College in August, 1937.

[2] Early publication of this paper has been secured by payment of the printing charge.

then being prodded if necessary, at the next regular observation in order to correct any errors in recording.

INSECTICIDES USED.—In the preliminary experiments, derris, calcium arsenate, and sodium fluosilicate containing 25 per cent colloidal silica were used alone and mixed with sulphur and with talc. During the more extensive experiments, calcium arsenate, acid lead arsenate, magnesium arsenate, sodium fluosilicate, barium fluosilicate, and cryolite were tested.

ANALYSIS OF INSECTICIDES.—The arsenic and fluorine compounds used in these experiments were standard products. The arsenicals were analyzed for total As_2O_5 content and the fluorine compounds for total F. (Association of Official Agricultural Chemists 1935). The percentage of total As_2O_5 in the arsenicals analyzed was as follows: calcium arsenate,[3] 42.7 per cent; acid lead arsenate,[3] 31.0; magnesium arsenate,[3] 33.0; and autoclaved calcium arsenate, 41.9 per cent. The total F content of the fluorine compounds was as follows: sodium fluosilicate, 57.5 per cent; sodium fluosilicate containing 25 per cent colloidal silica, 41.2 per cent; sodium fluosilicate containing 50 per cent colloidal silica, 28.0 per cent; barium fluosilicate, 37.0 per cent; and cryolite, 39.5 per cent F.

Table 1.—Percentage of mortality after exposure to insecticides, first test, 1934.

Insecticide	No. Insects in Experiment	Per Cent Mortality After Various Periods of Exposure		
		24 Hours	36 Hours	48 Hours
Derris (4%)	50	8	36	80
Sulphur	50	8	60	94
Sodium Fluosilicate (25% Silica)	50	20	94	100
Calcium Arsenate	50	32	96	100
None (Check)	50	6	22	34

RESULTS OF PRELIMINARY EXPERIMENTS, 1934.—The results of two preliminary experiments are shown by the data in tables 1 and 2. These data indicate that the insects used in the two tests were not of equal vitality since 34 per cent mortality occurred in the checks after approximately 48 hours in the first tests, whereas only 8 per cent occurred in the second. Likewise, the mortality resulting from the use of derris, sodium fluosilicate and calcium arsenate was 80, 100 and 100 per cent, respectively, as compared with 36, 80 and 100 per cent in the second. The insects in the two tests were not taken from the same population.

The data in table 2 indicate that talc was an effective diluent under the conditions of the experiment. Mixtures of talc with derris, with sodium fluosilicate and with calcium arsenate gave higher percentages of mortality than any of the materials used alone or mixed with sulphur.

Table 2.—Percentage of mortality after exposure to insecticides, second test, 1934.

Insecticide	No. Insects in Experiment	Per Cent Mortality After Various Periods of Exposure	
		24 Hours	48 Hours
Sodium Fluosilicate (25% Silica)	50	4	80
Calcium Arsenate	50	16	100
Derris (4%)	50	6	36
Sodium Fluosilicate and Sulphur	50	2	56
Sodium Fluosilicate and Talc	50	24	100
Calcium Arsenate and Sulphur	50	16	100
Calcium Arsenate and Talc	50	24	100
Derris and Sulphur	50	8	44
Derris and Talc	50	14	96
None (Check)	50	6	8

RESULTS OF CONTINUOUS EXPOSURE EXPERIMENTS, 1935.—The results of the continuous exposure experiments conducted in 1935 are presented graphically in fig. 1. The *per cent killed* in this graph represents the net mortality after the mortality in the checks has been deducted. Abbott's (1925) formula was used for the deducting of the mortality attributable to natural causes in making calculations of the percentage of kill. The order of effectiveness under the conditions of this experiment was magnesium arsenate > barium fluosilicate > calcium arse-

[3] Analysis by H. S. Swingle, Associate Entomologist, Alabama Polytechnic Institute.

nate > lead arsenate > cryolite > sodium fluosilicate. Some of the materials were almost equally effective. The approximate number of hours required to kill 50 per cent of the insects was as follows: for magnesium arsenate, 30.5; barium fluosilicate, 31.5; calcium arsenate, 35; lead arsenate, 38; cryolite, 40; and sodium fluosilicate, more than 60.

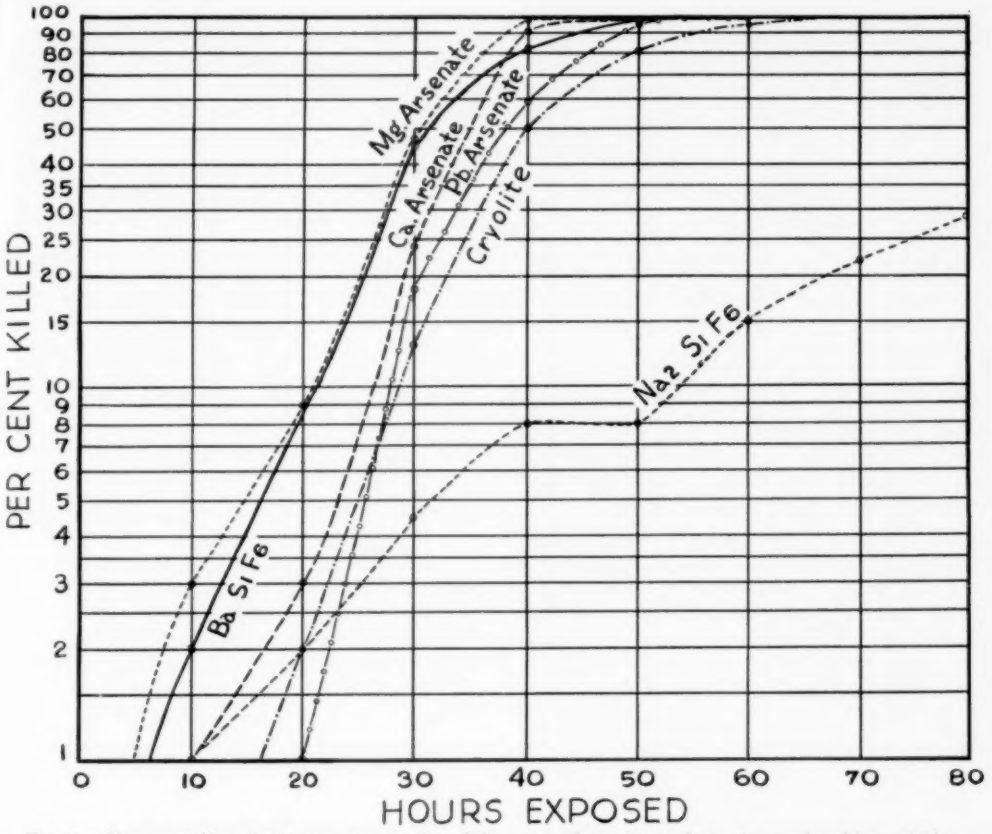

FIG. 1.—Net mortality of 600 cowpea curculio adults exposed continuously to six powdered insecticides.

RESULTS OF LIMITED EXPOSURE EXPERIMENTS, 1935.—The percentages of net mortality of insects exposed to the insecticide for a limited time are presented in fig. 2. In these experiments, three series of tests were made in which the insects were exposed to the dusts 6, 8, and 10 hours, respectively, before being transferred to food. Since there were no conspicuous differences in the results obtained in the three exposures, the data were averaged and the means were used in constructing the graph. Hence, the data presented in this graph are based on mortality records of 2400 insects, including checks.

The order of effectiveness under the conditions of these experiments, at 50 per cent mortality, was sodium fluosilicate > barium fluosilicate > calcium arsenate > magnesium arsenate > acid lead arsenate > cryolite. Some of the materials were of almost equal effectiveness, whereas others were decidedly different in efficiency. The approximate number of hours required to produce 50 per cent net mortality was as follows: sodium fluosilicate, 32; barium fluosilicate, 36.5; calcium arsenate, 50; magnesium arsenate, 70; lead arsenate, 100 hours. At the end of the experiment, sodium fluosilicate, barium fluosilicate and calcium arsenate appeared equally effective, the percentage of mortality being 91.2, 90.9 and 93.8, respectively. Magnesium arsenate, acid lead arsenate and

cryolite produced mortalities of 69.7, 48.9 and 14.6 per cent, respectively.

DISCUSSION OF RESULTS.—The data derived from the 1934 experiments are less nearly exact than those from later experiments in that fewer insects were used and observations were made at intervals not so closely approaching regularity. Yet the data are close enough to exactness to insure reasonable reliability.

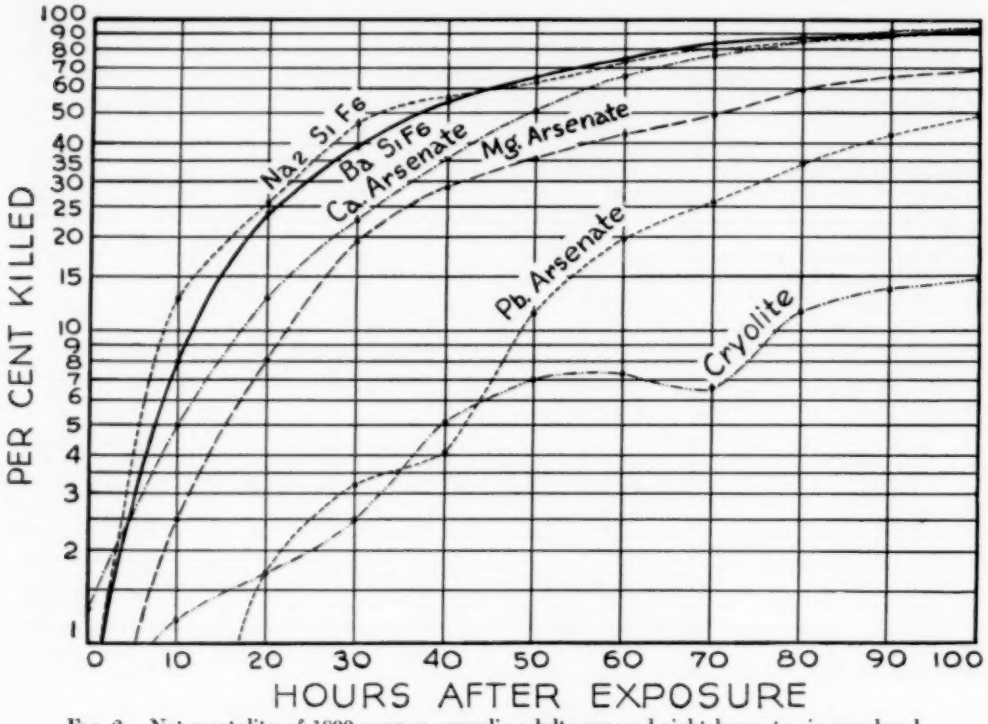

FIG. 2.—Net mortality of 1800 cowpea curculio adults exposed eight hours to six powdered insecticides and transferred to food.

The information obtained from these experiments was of primary value in planning the 1935 experiments.

Interesting differences were apparent in the relative efficiency of the insecticides as measured by the two different methods used in 1935. Sodium fluosilicate, the most effective insecticide tried in the limited exposure tests, fig. 2, seemed to be the least toxic in the continuous exposure tests, fig. 1. Magnesium arsenate, which was less efficient than calcium arsenate, barium fluosilicate and sodium fluosilicate in the limited exposure tests, appeared to be the most efficient material used in the continuous exposures; cryolite, by far the least efficient insecticide in the limited exposure tests, was almost as efficient as was lead arsenate in the continuous exposures.

These differences may be partially explained. The sodium fluosilicate "knocked out" the insects more quickly than any other material in the continuous exposure tests, but the insects apparently did not receive a lethal dose. After 16 to 24 hours all insects exposed continuously to sodium fluosilicate remained inactive and, upon superficial observation, appeared dead until the end of 92 hours at which time they became active and restless. Very little of the insecticide could be seen adhering to the insects. In all other materials the insects were active until they became moribund and finally died. Their bodies were coated with the insecticides to such an extent that they were mechanically entangled. The beetles struggled continuously in the dusts even after they were no longer able to crawl. It appears, therefore, that the lethal effect of the insecticides in the continuous contact tests was pro-

duced by a combination of factors: the toxicity of the insectides to protoplasmic constituents of the insect; the size of the dose, which was probably directly related to adhesiveness; and the mechanical effect of the dusts covering the body, entangling the appendages and perhaps entering the trachea. This interpretation is supported further by data from two other experiments.

In one of these experiments, 25 beetles were carefully weighed, exposed to a fluorine insecticide 30 minutes and reweighed. The fluorine compounds were used because of the variability in their effectiveness. The amount of insecticide adhering to each group of 25 beetles was as follows: barium fluosilicate, 0.0464 grams; cryolite, 0.0264 grams; sodium fluosilicate, 0.0147 grams. The apparent toxicity was directly related to the amount of adhering dust. The other data on the relation of adhesiveness to efficiency are from the 1934 experiments, table 2. The insecticides were invariably more efficient when mixed with talc than when used alone. Since tests on the efficiency of talc alone were not made, it might be argued that the increased efficiency was due to the true toxicity of the talc rather than its adhesiveness. This, of course, is possible since Richardson & Glover (1932) showed that large doses of talc and other inert substances were toxic to *D. duodecimpunctata* (F.). Talc was 100 per cent inefficient, however, in cage tests against the cowpea curculio, and it seems unreasonable to suppose the increased effectiveness of the mixed dusts resulted entirely from the true toxicity of the talc.

The foregoing discussion emphasizes the importance of the mechanical condition of the insecticide and its effect upon insects exposed continuously to the poison. The adhesiveness and other physical properties may be dominant factors in determining apparent toxicity. If, on the other hand, the insects are exposed to the insecticides for a limited time and then transferred to food, the mechanical effects of adhering dust are negligible. The length of the exposure determines to some extent the dosage, and the feeding of the insect insures the swallowing of material which otherwise might remain on the mouthparts. The ingestion of food and water is also important in that it is more nearly parallel to natural conditions than is the ingestion of a dry dust. It is obvious, therefore, that the limited exposure method described herein is more accurate and desirable for determining the relative efficiency of an insecticide to such insects as the cowpea curculio than is the continuous exposure method.

SUMMARY.—A suitable method of testing the efficiency of insecticides against the cowpea curculio consisted of confining the insect 6 to 8 hours in a Petri dish containing a film of the powdered insecticide, then transferring the insect to food, and making regular observations to determine the percentage of kill. Large numbers of the beetles were used, and tests of the various insecticides were conducted simultaneously. This method was decidedly more satisfactory than several others tried. Sodium fluosilicate, barium fluosilicate and calcium arsenate were about equally effective against the insect; magnesium arsenate, lead arsenate and cryolite were less effective in the order named. The percentages of net mortality at the end of the limited-exposure experiment were as follows: calcium arsenate, 93.8 per cent; sodium fluosilicate, 91.2; barium fluosilicate, 90.9; magnesium arsenate, 69.7; acid lead arsenate, 48.9; cryolite, 14.6 per cent. Talc was an efficient diluent with three types of insecticides, namely, sodium fluosilicate, derris and calcium arsenate. Preliminary experiments proved derris, pyrethrum, and 4-amino-di-phenyl to be relatively ineffective against the cowpea curculio. —3-16-38.

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Difficulties Encountered in Field Dusting Experiments[1]

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Some of the principal difficulties encountered in field dusting experiments are caused by localized infestation, the drifting of insecticidal dusts and the migration of insects. It is possible that an infestation of the insect may be localized in one part of the experimental area for considerable periods of time. Differences in infestation on different plots result in part from such localizations rather than from different treatments.

The recent trend in experimental work has been to replicate the treatments in Latin squares or similar arrangements. Such a plan is not only valuable in reducing the error from localized infestation, but is also desirable in yielding data suitable for statistical analysis. The replication of dusting experiments, however, does not entirely solve the problem. In fact it seems to present some new ones. Insecticidal dusts necessarily drift to some extent from the plots, on which they are applied, to adjacent plots. As a result, the replication or interspersing of treatments may increase the degree of error resulting from the drifting of insecticidal dusts. It may also increase the error caused by the migration of insects between plots.

PROCEDURE.—Replicated dusting experiments for field control of the cowpea curculio, *Chalcodermus aeneus* Boh., were conducted at the Alabama Agricultural Experiment Station in 1936. The experimental area, 286 feet long and 197 feet wide with 54 longitudinal rows, was divided into four tiers of four plots each. The tiers were separated by a 12-foot buffer strip. Each plot in a tier consisted of 10 rows and was separated from adjacent plots by 4 buffer rows. One-half of each buffer area received the same treatment as its adjoining plot. A diagram showing the arrangement and treatment of plots is presented in a Station bulletin (Arant 1938). Effective insecticidal dusts were applied to all plots except 1, 5, 12 and 13, which served as checks.

RESULTS.—In an effort to measure the effect of the drifting of dusts and migration of insects, a study was made of the infestation on the five rows of each check nearest a dusted plot as contrasted with the five rows farthest from the dusted plot. The results are presented in table 1. On all check plots the infestation was lower on the rows adjacent to the dusted peas than on the rows farther from them. The greatst difference in infestation occurred on plot 1. This was the only check plot having no dusted peas at either end. All other checks had adjacent dusted plots across one or both ends, as well as along one side of the plot. Plot 12, which had the second greatest difference in infestation, was 10 feet longer than the other checks; as a result, the peas for infestation counts were taken from an area farther from the ends than was possible on the other plots. The mean difference in infestation on all plots was 7.05 per cent. Based on odds of 19 to 1, this difference is significant as indicated by the following test:

Table 1.—Percentage infestation of the cowpea curculio according to location within check plots.

No. of Plot	Per Cent Infestation: Half of Check Next to Dusted Plot	Half of Check Away from Dusted Plot	Difference
1	30.35	42.44	12.09
5	35.12	38.51	3.39
12	22.36	32.35	9.99
13	21.79	24.53	2.74
Total	*109.62*	*137.83*	*28.21*
Mean	27.40	34.45	7.05

(1) Standard error of difference = 2.87,

(2) $t = 7.05/2.87 = 2.453$,

(3) $P = < .05$ for 6 degrees of freedom (Fisher 1934).

These data show that the cowpea curculio infestation on the check plots was reduced by applying insecticidal dusts to adjacent plots. If the infestation on check plots is so affected, then the infestation on dusted plots should likewise be affected by the treatment of their adjoining plots. As a result, one insecticide must be decidedly more efficient than another in order to produce a significantly different infestation on small plots with treat-

[1] Contribution from the Department of Zoology-Entomology, Alabama Polytechnic Institute, Auburn. This report is taken from a doctorate thesis presented to the graduate faculty of Iowa State College in August, 1937.

[2] Early publication of this paper has been secured by payment of the printing charge.

ments interspersed over the experimental area. Furthermore, the percentage of control on such plots is lower than would be expected if all the peas in an area were dusted. These factors must, of course, be considered in the interpretation of the results of field dusting experiments.—3-16-38.

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Internal Treatment of Animals with Phenothiazine to Prevent Development of Horn Fly Larvae in the Manure

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In a test to determine whether phenothiazine administered by mouth to an animal[2] would be of any value for destroying screwworm larvae infesting a wound, it was noted that manure from a calf under treatment was apparently unfavorable for the development of certain manure-breeding larvae. These observations were followed by controlled tests, the results of which are given herein.

Phenothiazine mixed with fresh cow manure was found to give 100 per cent control of larvae of the horn fly, *Haematobia irritans* L., in concentrations as low as 0.0025 per cent. Untreated manure under similar conditions gave approximately 75 per cent emergence.

CASE 1.—Three tests with cattle were made. In case 1, a 175-pound bull calf was fed 2 grams of phenothiazine, mixed with bran and oats, twice each day for 3 days. Manure collected 40 hours after the first feeding gave 100 per cent control of horn fly larvae in one test. After the third day the amount of phenothiazine fed to the calf was increased to 10 grams per day. This amount of phenothiazine was fed for about 2 months. During this period four tests were conducted in which 15, 15, 300, and 100 larvae, respectively, were implanted on fresh droppings. In another test approximately 200 eggs were allowed to be deposited on a fresh dropping by caged flies. In each test, 100 per cent control was obtained on the manure from the calf, whereas from 68 to 85 per cent emergence was obtained from manure from cattle which had received no phenothiazine.

CASE 2.—In case 2, a 250-pound bull calf was given a single feeding of 10 grams of phenothiazine in a mixture of bran and oats. The purpose was to determine how soon after feeding the manure inhibited growth of horn fly larvae and to determine how long the manure remained toxic. Alfalfa hay was available to the calf at all times after the phenothiazine had been given it. Two fecal droppings were taken before the experiment began and every dropping thereafter for 36 hours. One hundred active horn fly larvae were placed on each dropping. In all, 22 fecal droppings were collected during the 36-hour period. Droppings taken during the first seven hours did not inhibit the growth of horn fly larvae, but every dropping thereafter gave 100 per cent control of the larvae. Feces were also taken 51, 78 and 102 hours after the feeding. The manure collected 51 hours after the animal received phenothiazine did not prevent development of all of the larvae, although it was evident that the manure was toxic. The manure taken 102 hours after the phenothiazine was administered showed no toxicity.

CASE 3.—In case 3, a cow of two years, weighing about 600 pounds, was given daily doses of 20 grams of phenothiazine mixed with equal parts of colloidal kaolin

[1] Early publication of this paper has been secured by payment of the printing charge.

[2] In the tests described herein no immediate harmful effects on the animals by feeding phenothiazine were noted. Since this work was undertaken, the writer's attention has been called to a patent granted Floyd DeEds, Bureau of Chemistry and Soils, U. S. Department of Agriculture, and Clyde W. Eddy, San Francisco, Calif. (Patent No. 2085794, July 6, 1937), which describes the administration of phenothiazine to human begins as a urinary antiseptic. These investigators report that no ill effects were produced on man by administering the chemical by mouth at dosages of 0.01 to 0.25 grams per kilogram of body weight.

in about 300 cc. of water, for a period of 22 days. Manure was collected 24, 48, 72 and 90 hours after the last drench. Fifty 113, 101 and 81 horn fly larvae, respectively, hatched from eggs placed on each dropping, but no adult horn flies were reared from the manure. In the check fecal dropping, obtained from an untreated cow, 116 adults emerged from 125 eggs allowed to hatch on the manure.

DILUTION TESTS.—In addition to the tests discussed, dilution tests were conducted on two of the test animals to determine whether the manure contained an excess of the toxic material. In one test a mixture of 1 part of manure from the calf (case 1) receiving 10 grams of phenothiazine per day was mixed in 10 parts of manure from an untreated animal. This did not prevent development of the larvae, but in other tests on different occasions in which 1 part of manure from test animals was mixed in 2.5, 5.0, 5.0, 6.6 and 10 parts of manure from an untreated animal, 100 per cent control was obtained. In case 3, 1 part of manure collected from the cow 24 hours after it had received the last dose of phenothiazine, mixed in 6.6, 10 and 13.3 parts of manure from an untreated cow, prevented development of horn fly larvae.

SUMMARY.—In three cases phenothiazine administered to cattle at the rate of approximately 0.1 gram or less per kilogram of body weight prevented development of horn fly larvae in the manure that was eliminated by such animals.—3-14-38.

SCIENTIFIC NOTES

An Economical, Portable Light for Collecting Nocturnal Insects

A mercury vapor light offers many advantages over other lights for use in attracting nocturnal insects. The light is rich in those frequencies in the short wave-length end of the visible spectrum to which most insects respond readily; mercury vapor is far superior, in this respect, to neon.

The predominating lines in the spectra of the three commonest commercial luminous tube lights are shown in fig. 1; the sections of these spectra filtered out by the glass tubing itself are indicated by broken lines. It can be seen that in the red, or neon, light the majority of the strong lines are in the red and orange end of the spectrum, while almost all of the strong lines in the spectrum of the mercury vapor light lie in the blue end. The common green commercial luminous tube light is argon gas and mercury vapor inside yellow glass; the latter eliminates all but a few strong yellow and green lines of the mercury spectrum. Argon gas alone gives a faint yellowish-white light and shows no strong lines in the visible spectrum. In the making of commercial mercury vapor lights, argon is added to lower the required operating voltage and make striking easier. A combination of neon and mercury gives a purple light considerably less brilliant than argon and mercury, when the same voltage is applied to both.

Each light, it must be remembered, actually contains a mixture of diverse color lines, in spite of the predominance of one visual color. This makes their use for scientific experiment very limited.

When the three lights whose spectra are shown in fig. 1 were set up together on a warm midsummer evening and the same voltage applied to all, it soon became apparent that very few insects were attracted by the green light. A few, especially the higher Diptera, were attracted by the red; the very great majority were, however, attracted by the blue. Despite the fact that all of these lights consume the same amount of current and appear to be of about equal intensity, the mercury vapor is much more effective than either the red or green for general nocturnal collecting.

The mercury vapor light operates at a low temperature, so that insects are not at all likely to be killed by the heat. The average dissipation by these tubes is only three watts per foot. The light, also, is emitted uniformly over a relatively wide area, and not concentrated in a small point, as in incandescent or flame lights. This last characteristic of luminous tube lights is quite advantageous, as the insects do not crowd over and crush each other in an attempt to reach the one spot of maximum brilliance.

If the mercury vapor tube is to glow, however, a high voltage must be applied. The general operating voltage for these tubes is approximately 800 volts per foot, although this can be varied within wide limits. Usually 2500 volts is satisfactory for a tube three or four feet long; a higher voltage increases brilliance slightly, but a voltage much lower is likely to cause intermittent operation. There is, of course, no difficulty in obtaining the necessary high voltage by means of a transformer when 110-volt alternating current is available. It is often desirable, however, to operate a light trap by using a mercury vapor tube where such current is not available. The following arrangement, has therefore, been devised to enable a mercury vapor light to be operated from a six-volt direct current source and used as a portable light to be set up anywhere in the field where collecting is desirable.

Fortunately, the current consumed by these tubes is extremely small: the light described here uses only .004 amperes. This low current drain makes it possible to secure adequate operating voltage from the secondary of a Ford Model T induction coil. The electrical diagram of this light is shown in fig. 2. T_1 is the ignition coil; C_2 is the condenser which comes sealed within this unit. The capacity of this condenser influences, to a considerable extent, the voltage obtained from the unit. When no current is being drawn from the secondary, the voltage across it is approximately 50,000 volts. When a three-foot

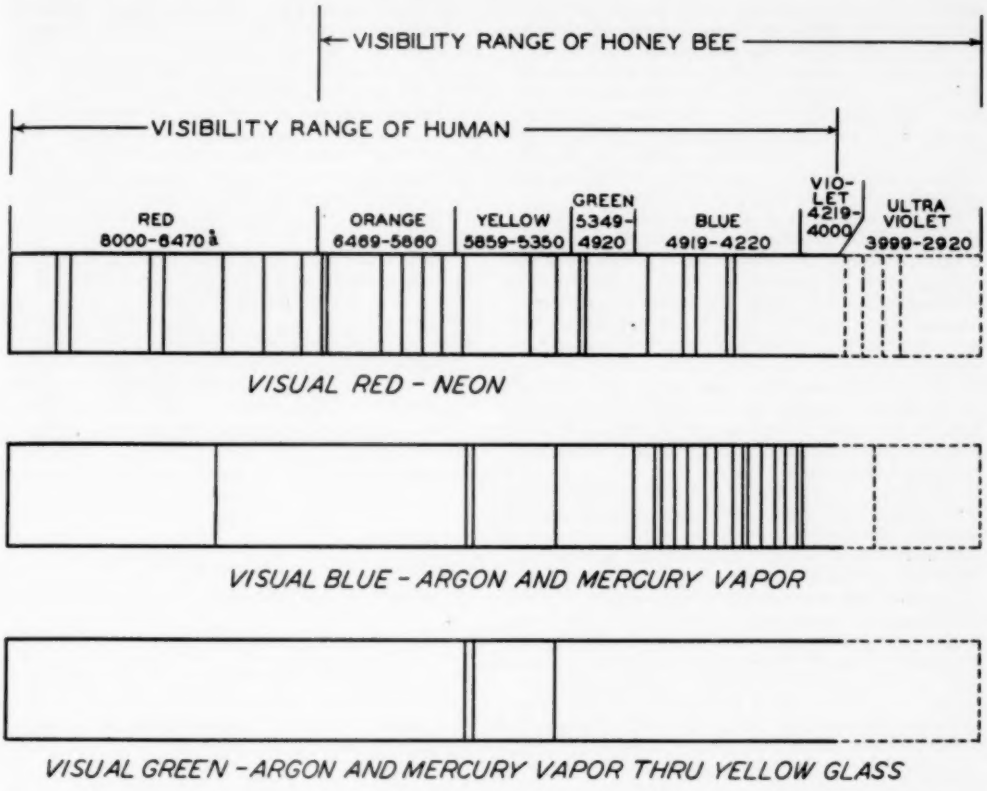

FIG. 1.—Band spectra of three common commercial luminous tube lights, appearing red, blue and green to the human eye. The glass of the tube absorbs all the ultra-violet rays, indicated by broken lines.

mercury vapor tube is, however, connected across the secondary the voltage falls to about 2500 volts. In the diagram, R_1 represents the mercury vapor

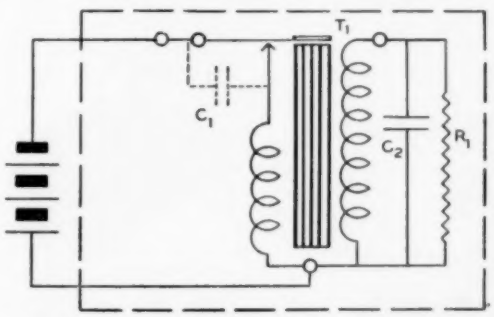

FIG. 2.—Diagrammatic hook-up of portable light shown in fig 3.

tube. Increasing the size of C_2 by .1 mfd. would increase the voltage applied to the tube with a consequent increase in brilliance, but this would likewise increase the amount of current drawn from the battery in the primary circuit. A three-foot tube shunted across the secondary of the Ford coil without the addition of an external condenser causes a current drain of 1.5 amperes from the six-volt bat-

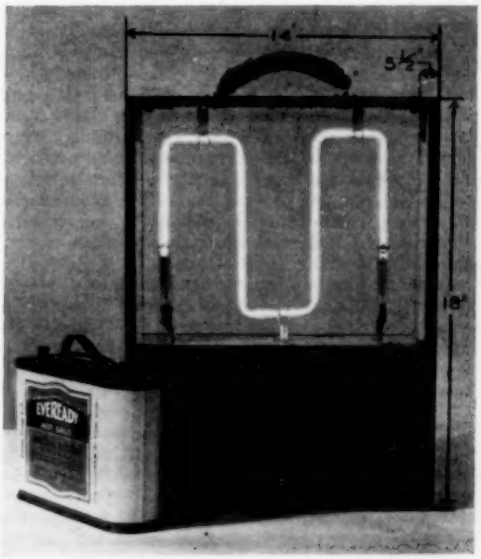

FIG. 3.—Portable light for collecting nocturnal insects. Battery and arrangement of argon-mercury glow tube are shown.

tery in the primary circuit. This is high enough if economical operation is to be secured when using no. 6 dry cells. If the six-volt storage battery of an automobile is to be used, there is, of course, no objection to drawing considerably more current than this. Condenser C_1, shown in the diagram shunted across the interrupter in the primary circuit of Y_1 may be a 1.0 mfd., low voltage condenser; the addition of this will help somewhat in eliminating the rather objectionable flicker of this light.

Fig. 3 is a photograph of the portable light which has been found most useful for use in the field. This is light in weight, but strong; many mechanical difficulties were eliminated by keeping the battery external to the light itself. The upper compartment contains the glow tube, and the lower houses the induction coil and a cord and plug. The cord can be connected either to the terminals of a *Hot Shot* battery or be connected to a male plug to be inserted in the tail light socket of an automobile. The wires leading from the induction coil to the glow tube must be kept short and well separated, because of the high voltage used.

The box is made of plywood and, consequently, must be finished so as to be moisture proof. Triple strength window glass should be used in the upper compartment, to reduce the possibility of breakage. This light weighs 11 pounds, and the battery weighs 10 pounds; the entire unit can be built for $13.00, including the battery.—11-15-37.

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Aphomia gularis Zeller as a Pest of Prunes

De Ong (1919) has published notes on a heavy infestation by the moth *Aphomia gularis* Zeller, in a California warehouse, in peanuts imported from China.

In 1927 reports were received of a new type of infestation in stored prunes in the San José district of California. Investigation by members of the staff of the dried fruit insect laboratory of the Bureau of Entomology and Plant Quarantine, which is located at Fresno, Calif., revealed a limited infestation in prunes in one packing house. For the succeeding seven years occasional observations were made in the San Francisco Bay area, of which San José is a part, and specimens of *Aphomia gularis*, or evidences of its presence and work (chiefly strong, heavy webbing and cocoons), were found in one plant in San José but in no other location.

During a survey of storage plants in this area in February, 1935, infestations were found in prunes in several San José storages and in one in Oakland. In the Oakland storage many larvae were crawling over bags of almonds in the same room. The almonds had been fed on by insects, but no larvae were actually observed feeding. Other surveys in San José in 1936 and 1937 have shown the species in every plant visited, and evidences of serious loss in most of them. In the same plants quantities of other dried fruits—mainly apples, pears, peaches, and apricots—were stored also, often in adjoining bins, but prunes were the only fruit found attacked.

Well-grown *Aphomia* larvae are over an inch in length and are voracious feeders. Many prunes showing feeding consist of nothing more than pits scantily covered with bits of flesh and quantities of coarse black excreta and white webbing. Cocooning for pupation occurs largely in cracks of bins, beneath or in the bottoms of boxes and adjoining other wooden materials. Frequently shallow cells are cut from the wood and the cocoons spun within.

Aphomia gularis is obviously increasing in importance as a stored-prune pest, and is slowly widening its distribution. Because of the danger of introcing the species into the prune and almond districts surrounding Fresno, no living specimens have been brought to the laboratory for studies of development.

Since it is becoming an increasingly important factor in storage of prunes, and is not known as a serious pest of any other material, the writers suggest that the common name "dried prune moth" be given this insect.—2-4-38.

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Glossonotus crataegi Fitch. Susceptible to Dormant Oil Sprays

A dormant application of lubricating oil emulsion, 6 per cent oil, applied for the purpose of controlling an infestation of the fruit-tree leaf-roller, *Archips*

FIG. 1.—*Glossonotus crataegi* on apple twig. Slightly larger than half natural size.

argyrospila Walk., also gave very good control of a heavy infestation of the tree hopper, *Glossonotus crataegi* on apple. Fig. 1 shows the insect on an apple twig. Fig. 2 gives a close view of the insect.

Unsprayed twigs placed in water early in the season prior to the opening of the buds and held at room temperature produced large numbers of the

FIG. 2.—*Glossonotus crataegi*. Slightly larger than twice natural size.

tree hoppers while twigs that had been treated with a dormant oil application showed only an occasional insect. Both 3 and 6 per cent strengths of lubricating oil killed a majority of the eggs in the twigs and very few hoppers emerged. Three per cent coal gas tar oil appeared to have no influence on the eggs.

A count of eggs on twigs taken from an orchard that had been sprayed with a dormant application of 6 per cent lubricating oil gave the following figures. The counts were made 11 days after the normal hatch.

Total eggs counted	156
Number of eggs hatched	39
Number of eggs unhatched	117
Percentage eggs killed by oil	75%
Percentage eggs not killed	25%

—12-27-37.

S. W. HARMAN, *New York State Agricultural Experiment Station, Geneva.*

Cottonseed-Hull Bran in Grasshopper Bait

Experiments conducted at State College, Mississippi, in July indicate that cottonseed-hull bran is about as effective as wheat bran as a carrier for poison in grasshopper bait. At present this material is used chiefly for diluting cottonseed meal to cut down its analysis and the cost is very reasonable, being only one-fifth that of wheat bran.

Laboratory tests seemed to indicate that a mixture of three parts hull-bran to one part wheat bran was slightly more effective than the 100 per cent hull-bran but under field conditions there seemed to be little difference. This may be accounted for by the fact that the laboratory tests were conducted with *Melanoplus differentialis* (Thos.) while in the field tests *Schistocerca americana* (Drury) was used. The material was tested on a severe infestation of the latter species on the experiment station farm and furnished a good opportunity to compare the effectiveness of 100 per cent wheat bran, 100 per cent hull-bran, and various mixtures of the two. Future tests may indicate that it is advisable to use a mixture of hull-bran and wheat flour, about one to ten, to prevent the rapid drying which is characteristic of the hull-bran bait. This might be especially desirable in a dry climate. The bait found most effective under field conditions at State College was one consisting of:

Hull-bran	100 lbs.
Sodium arsenite or Paris green	5 lbs.
Amyl acetate	4 oz.
Molasses	2 gal.
Water	7 gal.

It will be noted that this mixture requires slightly less water than the usual wheat bran mixture.—11-17-37

ROSS E. HUTCHINS and CLAY LYLE, *State Plant Board, State College, Mississippi.*

Higher Ketones as Intermediary Solvents for Derris Resinate Used in Petroleum Spray Oil

Investigators have found the powdered root of Derris elliptica (Deguelia) and cubé root to be toxic to a number of insects. The compound most toxic to insects in the powdered root is rotenone. Derris resinate, which appears to be toxic to several insects when incorporated with certain solvents and used with citrus spray oils, is the material that is extractable from the powdered root when acetone, ethyl ether, or other solvents are used. The solvent is distilled off, leaving the resinate as a gummy mass.

In the summer of 1935 a study was made of the toxicity of the powdered derris root mixed with various organic solvents. It was believed that by making a paste of the derris powder before it was added to the oil, some of the rotenone and resins would be extracted, thus increasing the efficiency of the mixture. Several plots consisting of Washington Naval orange trees infested with black scale, *Saissetia oleae* (Bern.), were sprayed with various dosages of this material. The results were not satisfactory.

Acetone and ethyl ether derris extracts were also used with low percentages of spray oil, but certain difficulties were encountered such as the resins flocculating and going out of the oil phase into the aqueous phase.

During the winter of 1936–37 tests were made on a number of organic solvents from the standpoint of (1) the solubility of the derris resinate in the solvent; (2) the solubility of solvent in the spray oil; (3) the solubility or suspensibility of the derris resinate-solvent mixture in the spray oil; (4) the solubility of the solvent in water; and (5) the toxicity of the mixture to certain scale insects. The main groups of the solvents tested were: (1) alcohols, (2) alcohol-ethers, (3) ethers, (4) glycols, (5) aldehydes, (6) ketones, (7) esters, (8) aliphatic amines, (9) chlorinated products of the saturated hydrocarbons, (10) phenols, (11) benzene and benzene derivatives, and (12) the essential oils. Only a few compounds in each group were tested. The higher ketones appeared to give the best results from the standpoint of solubility of the derris resinate, stability of the resulting mixture, and added toxicity to the spray oil. Other compounds such as 2,2′ dichlorethyl ether, sassafras oil, and the higher acetates appeared to be good solvents for derris resinate, and experimental data seem to indicate an added toxicity to the spray oil. California red scale, *Aonidiella aurantii* (Mask.), was used as the test animal.

Derris resinate is not very soluble in highly refined petroleum oil such as is used in the spraying of citrus. Thus, when an appreciable amount of the derris resinate-solvent mixture is added to the oil, a suspension of resins and rotenone is formed.

In the early part of 1937 laboratory experiments were made using methyl isobutyl ketone, methyl-n-amyl ketone, and 2,2' dichlorethyl ether as intermediary solvents for the derris resinate and tank mix spray oil. Lemons infested with California red scale were used for the experiments. Derris resinate dissolved in methyl-n-amyl ketone appeared to give the best kill of the three solvents. Ebeling* has shown that methyl-n-amyl ketone incorporated in spray oil increases the toxicity of the oil to the red scale. Further laboratory and field work by Ebeling during the summer and fall of 1937 also substantiates the above findings with regard to the toxicity of derris resinate to red scale. He also found that the methyl-n-amyl ketone-derris resinate solution increased the toxicity of the oil to the Florida red scale, *Aonidiella aonidum* (Linn). The derris resinate-methyl-n-amyl-ketone-oil mixture has been tested on the citricola scale, *Coccus pseudomagnoliarum* (Kuw.), and black scale, *Saissetia oleae* (Bern.). The results indicate an added toxicity to the oil to both insects. A paste formed by the addition of methyl-n-amyl ketone or 2,2' dichlorethyl ether to the derris powder seemed to increase the efficiency of the material.

This is a preliminary note and additional work is being carried on with high ketones and other solvents for carrying derris resinate.—2-2-38.

J. P. LA DUE, *University of California Citrus Experiment Station, Riverside.*

Methyl Iodide as a Fumigant

Of the many chemicals tried as fumigants in the past six months, methyl iodide seems to show the most promise. Methyl iodide, CH_3I, contains approximately 89 per cent iodine, is a colorless to brown liquid, has a boiling point of 42.5 degrees C. and a specific gravity of 2.285. It is slightly soluble in water, 1.4 grams per 100 cc. of water at 20 degrees C. and is soluble in all proportions in alcohol and ether.

The first tests with methyl iodide were tried in a 13 liter bell jar, and later in a 12½ cubic ft. fumatorium, and then in a 100 cubic ft. fumatorium. Tests have been carried on at exposures of 1 hour, 1½ hours, 3 hours, and 5 hours with a temperature of 76–80 degrees F. Large numbers of the following insects have been tried: resistant and non-resistant red scales, confused flour beetles, lady beetles, and codling moth larvae, as well as fewer numbers of other insects. A few tests conducted on citrus seedlings have shown that concentrations considerably above those which are lethal to the insects tried were not toxic to the plants.

The results in all cases indicate that this compound has possibilities as a fumigant. At the present time methyl iodide is very expensive, but if produced in large quantities, the price may be considerably reduced.—1-31-38.

D. L. LINDGREN, *University of California Citrus Experiment Station, Riverside.*

* Unpublished data, Dr. Walter Ebeling, Citrus Experiment Station, Riverside, California.

Bacteria Isolated from the Gut of Larval *Agriotes mancus* (Say)

In biological literature one finds references to the various types of bacteria found in the digestive tracts of insects and to the symbiotic relationships existing between micro-organisms and their hosts. From recent nutritional investigations one would conclude that bacteria furnish certain substances essential for the life processes of insects because little or no growth results from a diet of sterilized food unless the required accessory factors are supplied. This preliminary investigation was conducted in order to study the types of bacteria found in the gut of the wireworm.

Larvae of *Agriotes mancus* (Say) were collected from infested potatoes from the fields in the potato growing area of New York state. The larvae were made externally aseptic by using a sterilizing mixture of equal parts 1:1000 mercuric chloride and 80 per cent alcohol. Live wireworms were sterilized for 5 minutes in about 10 cc. of the sterilizing solution in a sterile Petri dish and were transferred to sterile distilled water for washing. The aseptic larvae were ground with sterile sand in a sterile mortar. The mixture of sand and larvae was transferred to a sterile water blank and various dilutions were plated on nutrient agar. The average count was approximately 550,000 bacteria per larvae. The greatest number of bacteria was found in the hind-gut. Many isolations were made and of these, 15 per cent were starch hydrolyzers and 75 per cent were proteolytic, as demonstrated by gelatin liquefaction. In all probability the larvae did not depend upon bacteria to aid in food assimilation.—1-19-38.

R. M. MELAMPY and G. F. MACLEOD, *Department of Entomology, Cornell University, Ithaca, N. Y.*

Massing of Convergent Ladybeetle at Summits of Mountains in Southeastern United States*

The convergent ladybeetle, *Hippodamia convergens* Guer., is an abundant beneficial species in the southeastern states as well as in other parts of the country. It has long been on record that on the Pacific Coast it gathers gregariously in canyons and ravines in mountains for the winter.

In *Ecology* Vol. XVI No. 1, January, 1935, page 125, Alvin H. Throne of State Teachers College, Milwaukee, records finding this species at highest point on north range of the Porcupine Mountains, Ontonagon County, Michigan, on September 1, 1934: "millions clustered on bushes, etc." apparently gathered "preparatory to hibernation for the winter." The locality is in the western portion of the upper peninsula of Michigan, and those Mountains give the highest elevations in that state.

Several other species of ladybeetles are known to hibernate gregariously.

The purpose of these notes is to show that the convergent ladybeetle assembles in masses at summits of high mountain peaks (not ravines) in the southeastern states, and that this phenomenon apparently has no connection with hibernation. Our observations covering all seasons except spring, and reports of others, are recorded in table 1.

* No. 52 of Journal series, South Carolina Agricultural Experiment Station.

Table 1.—Massing of convergent ladybeetle at summits of high mountain peaks in southeastern United States.

PLACE	DATE	COMMENTS	OBSERVER
Pinnacle Mt. S.C., about 3,400 ft.	Aug. 3, 1926	Countless thousands clustered on weeds, bushes, among old leaves, etc.	F. Sherman, J. A. Berly, J. O. Pepper
Sassafras Mt., S. C., N.-C. state line, about 3,500 ft., highest in vicinity	June 21, 1932	(details below)	F. Sherman
Rabun Bald Mt., Ga., highest in vicinity	June 13, 1933	Masses found	F. Sherman
Mt. Pisgah, N. C., 5,749 ft., highest in vicinity	Aug. 21, 1932	Great masses seen	D. L. Wray
Mt. Pisgah, N. C., 5,749 ft., highest in vicinity	(date not recorded)	Great numbers presumably this species	Reported to F. S. by a visitor, name not taken.
Paris Mt., near Greenville, S. C., highest in vicinity	Feb. 3, 1933	Masses seen	Henry K. Townes
Mt. Sterling, Haywood County, N. C., one of highest in vicinity	(date not taken)	Great numbers seen, presumably this species	Reported to F. S. by attendant at meeting S. C. Academy of Science, Apr. 21, 1934.
Kings Mt. National Military Park, S. C., highest in vicinity	July 18, 1934	Masses seen at very summit	J. A. Berly
Mt. Mitchell, N. C., 6,711 ft., highest in eastern U. S.	Aug. 10, 1934	Masses observed	J. S. Holmes, State Forester of N. C.

The foregoing includes South Carolina, Georgia, North Carolina, and the Mount Sterling record perhaps touches Tennessee.

Returning now to Sassafras Mountain (Pickens Co., S. C.—Transylvania Co., N. C.) the highest point in South Carolina. The writer has there seen masses of this species many times, as now shown:—

Sassafras Mt., S. C., N. C. state line, about 3,500 ft., highest in vicinity	June 21, 1932	Masses; some in flight, but movement almost nil in assembled masses.
Sassafras Mt., S. C., N. C. state line, about 3,500 ft., highest in vicinity	July 30, 1932	Masses; search at bottom and under masses did not reveal dead ones nor remains.
Sassafras Mt., S. C., N. C. state line, about 3,500 ft., highest in vicinity	Aug. 9, 1932	Masses; D. Dunavan and O. L. Cartwright made several photographs.
Sassafras Mt., S. C., N. C. state line, about 3,500 ft., highest in vicinity	Aug. 24–25, 1932	Masses; 20 hours repeated observations as detailed in text.
Sassafras Mt., S. C., N. C. state line, about 3,500 ft., highest in vicinity	Oct. 12, 1932	Masses present, but seemed diminished.
Sassafras Mt., S. C., N. C. state line, about 3,500 ft., highest in vicinity	Jan. 20, 1933	Some clearing away of growth has been done on summit; several inches snow a month ago; masses present but scattered, in grass tufts close to ground.
(Did *not* find masses on visits May 31 and June 1)		
Sassafras Mt., S. C., N. C. state line, about 3,500 ft., highest in vicinity	June 21, 1933	Masses present; notes say that from flight activity I suspected they were assembling. (Apparently more arriving than departing.)
(Did *not* find masses on Oct. 6; no dead ones found where masses were previously)		
Sassafras Mt., S. C., N. C. state line, about 3,500 ft., highest in vicinity	July 31, 1934	Masses present, notes say:—"in greater numbers than I have before seen on this mountain."
Sassafras Mt., S. C., N. C. state line, about 3,500 ft., highest in vicinity	Sept. 4, 1934	Masses present; (notes):—"perhaps the aggregations more scattered than last time; I estimate a gross total of a bushel or more."
Sassafras Mt., S. C., N. C. state line, about 3,500 ft., highest in vicinity	June 19, 1937	Much more clearing has been done—one mass of perhaps two quarts of the beetles found.

On August 24, 1932, the writer went to top of Sassafras Mountain (S. C.—N. C. state line) with Messrs. D. Dunavan and O. L. Cartwright of the Clemson College entomology staff, arriving about 4 P.M. Remained until 1 P.M. next day, making frequent observations with lantern and flashlight until midnight, and resumed observations at about 6 A.M. The masses of lady beetles were quiescent as heretofore, and throughout the time of our visit no general activity was observed:—masses exposed to sunshine became more active while the sun shone on them, some would fly away and others would arrive, yet as a whole the masses showed little movement. At times one might see several beetles in flight

FIG. 1.—Massing of convergent ladybeetle on green oak sprouts two to three feet above ground. Others at base and on ground below. Summit of Sassafras Mountain, along South Carolina-North Carolina line, August 9, 1932.

at one time, but nothing like the swarming of bees, nor even like the usual flights before a hive. As night approached and all through the night the clusters of beetles remained as they were, those in exposed situations remaining exposed and those in sheltered situations remaining sheltered. There was less of crawling and flying as the sun went down, through evening, and night. In general there appeared to be more activity than on July 30 (a previous visit) but I watched them over a longer time and the sunshine was if anything brighter and warmer than on that date. No general movement by or among them, was yet in evidence.

In pondering as to the reason for these assemblages of *H. convergens* the following ideas occur:

1. *Hibernation:* That this has anything to do with it seems denied by finding these masses already assembled from June 19 to August 25 though early and middle summer, months before cold weather. Also many were not especially hidden away under shelter, nor did they seem to seek it.

2. *Aestivation:* This seems denied by having found the assembled masses on September 4, October 12 and January 20. Also many in these masses quietly remain exposed in the sunlight with no attempt to seek shade or other shelter.

3. *Food:* On no occasion have we found aphids or other natural food present or near in unusual abundance, nor evidence of such having been present. Also we have seen no evidence of hunger-urge. Instead of scattering and searching, their desire seems to be to assemble and remain quiet.

4. *Mating:* No abnormal amount of copulation-activity has been observed. If anything, there seems to be less thaa we would expect among so many.

5. *Spent, assembled to die:* Careful search has revealed surprisingly few (almost none) dead ones or remains in spots where gallons of them had been assembled on our previous visits, nor did we find dead or dying ones among or under the assembled masses.

Thus each of the possible explanations which would first come to mind seems denied by the observed facts. And the writer has no adequate explanation.

It seems worthy of repetition that these assemblages have not been in ravines or specially sheltered situations. They have been on the highest summits in the respective localities, on the lower portions of such low growth as may be there, as well as in base of grass-tufts, under old leaves on the ground and the like. On low oak sprouts for example, they may be massed (in summer) from the base up to and upon the growing green leaves as much as three feet above the ground, often several deep, newcomers crawling over those already assembled as shown in fig. 1—2-19-38.

FRANKLIN SHERMAN. *Clemson College, S. C.*

Organic Compounds Highly Toxic to Codling Moth Larvae

The Division of Insecticide Investigations of the Bureau of Entomology and Plant Quarantine has been engaged since 1932 in seeking substitutes for the arsenicals, more especially lead arsenate. In the course of this work several hundred organic compounds have been prepared and tested. A detailed report covering all compounds tested by the writers up to July 1, 1936, will be published separately. Those compounds found most toxic to codling moth larvae are reported at this time in the hope that entomologists will be encouraged to test them upon other insects of economic importance.

All tests reported in this paper were made by the apple-plug method (Siegler & Munger 1933; Siegler, Munger & Gahan 1934).

A great majority of the organic compounds tested were difficult to wet in water and therefore did not give uniform suspensions. In an attempt to improve this condition, various wetting agents, such as bentonite and ethyl alcohol, were employed.

Of the compounds tested, those listed in table 1 gave over 50 per cent of fruit free from worms.

It should be borne in mind that the relative ratios of stung and wormy fruit in these experiments varied greatly with the different compounds reported.

Of over 200 organic compounds tested, only the 20 listed gave more than 50 per cent of fruit free from worms. One compound, 3,5-dinitro-*o*-cresol, has been found toxic to codling moth larvae by other investigators. It is interesting, however, to note that by replacing the phenolic hydrogen in this compound by either an acetyl or a methyl group the resulting compound still shows high toxicity. Twelve of the toxic compounds contain nitrogen, in one of which (namely, 1-phenylbenzoxazole) the nitrogen is in a heterocyclic ring. Seven of the compounds contain sulfur. In four of these seven compounds the sulfur

Table 1.—Compounds tested which gave over 50 per cent of fruit free from worms:

COMPOUND	PERCENT OF FRUIT FREE FROM WORMS
3,5-dinitro-*o*-cresol	100.0
p-iodonitrobenzene	100.0
2-thiocoumarin (average 2 tests)	97.2
phenothioxin (average 3 tests)	93.5
1-phenylbenzoxazole	92.0
3,5-dinitro-*o*-cresol acetate	90.5
m-iodonitrobenzene	83.3
2-methyl-4,6-dinitroanisole	75.3
dibenzothiophene	73.6
p-bromobiphenyl	72.7
p-bromonitrobenzene	72.7
pentachlorophenol	68.6
thioxanthydrol	66.0
m-dinitrobenzene	60.8
p-nitrosodimethylaniline	60.0
diphenyldisulfide	59.0
thioxanthone	59.3
1-nitroso-2-napthol	57.8
acetone semicarbazone	54.3
thiocarbanilide	52.7

is in a heterocyclic ring. There are six compounds containing a heterocyclic nucleus and five that are halogenated. These studies fail to show any simple relationship between the constitution of organic compounds and their toxicity to insects.—12-17-37.

L. E. SMITH, E. H. SIEGLER and F. MUNGER, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine.*

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Siegler, E. H., F. Munger and J. B. Gahan. 1934. Improvement in apple plug technique for toxicological studies of the codling moth. JOUR. ECON. ENT. **27**(6):1140–2. Illus. Dec.

Synonomy of the *Euscepes* Sweetpotato Weevil (Coleoptera, Curculionidae)

Because my paper "Cryptorhynchinae of the Society Islands" is in a publication infrequently seen and rarely referred to by economic entomologists, I believe it worthwhile to reconsider in this journal my nomenclatorial findings concerning *Euscepes batatae* (Waterhouse), commonly called the West Indian sweetpotato weevil.

Unfortunately, it has been found necessary to change the name of the common, widespread, cryptorhynchine weevil pest of sweetpotato, *Euscepes batatae* (Waterhouse). This species has been incorrectly masquerading as a "lost species" under the name *Cryptorhynchus postfasciatus* Fairmaire. Fairmaire described the species in 1849 from a unique specimen collected on Tahiti in the Society Islands.

While working over the material I collected during the course of the Mangarevan Expedition to southeastern Polynesia in 1934, I found that Fairmaire's species was identical with the sweetpotato weevil. Furthermore, it was found that Fairmaire's name antedates that of Waterhouse, necessitating additional synonymy. Unless it is shown in the future that there is an older name, this sweetpotato weevil shall be known as follows:

Euscepes postfasciatus (Fairmaire) Zimmerman: B. P. Bishop Mus. Occ. Papers, vol. 12, no. 23, p. 14, 1936.

Cryptorhynchus postfasciatus Fairmaire: Rev. Mag. Zool., p. 513, 1849 (in reprint, p. 65, June 1849).

Cryptorhynchus batatae Waterhouse: Proc. Ent. Soc. London, p. lxix, 1849 (printed 1850).

Hyperomorpha squamosa Blackburn: Trans. Roy. Soc. London, ser. 2, vol. 3, pp. 182–183, 1885.

Euscepes batatae (Waterhouse) Champion: Biol. Centr. Amer., Coleoptera, vol. 4, pt. 4, p. 497. 1905.—12-27-37.

ELWOOD C. ZIMMERMAN, *Bernice P. Bishop Museum, Honolulu, T. H.*

Distribution of Elm Bark Beetles in Massachusetts

A survey of the distribution of smaller European elm bark beetles in Massachusetts, conducted by the State Dutch Elm Disease Laboratory at Amherst during the summers of 1935, 1936 and 1937 showed *Scolytus multistriatus* Marsham to be present in the following towns. WESTERN MASSACHUSETTS: Great Barrington and New Marlborough. EASTERN MASSACHUSETTS: Merrimac, Haverhill, Methuen, Tyngsborough, Tewksbury, Andover, North Andover, Boxford, Georgetown, Topsfield, Wenham, Beverly, Danvers, Billerica, Reading, Woburn, Stoneham, Saugus, Revere, Winthrop, Lexington, Sudbury, Weston, Waltham, Belmont, Newton, Brookline, Boston, Wellesley, Natick, Dover, Westwood, Walpole, Canton, Easton, Abington, Rockland, Brockton, Marshfield, Bridgewater, East Bridgewater, Halifax and Plymouth. These findings do not include those previously reported by this office [W. B. Becker, JOUR. ECON. ENT., **28**(5): 833].

Hylurgopinus rufipes (Eich.) was found to be distributed in every section of the state scouted. The only sections not scouted were Cape Cod and the islands off the coast.—12-1-37.

W. B. BECKER and W. E. TOMLINSON, Dutch Elm Disease Laboratory, Department of Entomology, Massachusetts Experiment Station, Amherst.

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Our Goal—Service, Cooperation, Better Living

PERHAPS it may be well if we stop a moment to reflect on our activities and evaluate our efforts in terms of objectives or goals. Are we directing our efforts for the best of the profession of entomology and for humanity, or are we giving our efforts to the things of greatest personal interest or those which offer the least resistance? Are we maintaining a cooperative attitude in our work, recognizing the work of others and cooperating with workers in our own and other sciences to insure the greatest returns, not for ourselves but for the human race? Are we thinking in terms of serving the people, who are in most cases financially supporting our studies, or are we conducting our work with personal benefits uppermost in our minds, or perhaps with an idea of discrediting our colleagues?

During the past few years we have observed cases where the worker's personal interests were his uppermost thoughts, where the course of least resistance was being followed, where there was no thought of cooperation, where the major effort seemed to be to disqualify the activities of others, or to give no consideration of permanent service to the human race.

Doctor L. O. Howard, in his memorable volume, *The Insect Menace*, has written: "We focus our attention on the immediate. We seek the quickest and the cheapest remedies. We wish to stop the momentary danger, and we wish to destroy our enemies in such numbers as to reduce the loss at once. But we must not ignore fundamentals. We must search for underlying principles." What is the goal or objective of economic entomology? To me it is conservation—in popular usage now-a-days—in its broadest sense. Again, in *The Insect Menace*, we read: "There is a third way of assisting in the feeding of the world, aside from birth-control or the stimulation of plant food or the invention of new food, and that is the stopping of all waste. Probably the greatest of these wastes is the tremendous but unnecessary tribute that we pay to insects. In the United States alone the labor of one million men each year is lost through damage done by insects to crops and to our other vital interest. And this damage is increasing."

It would seem to us, therefore, that our ultimate goal is to insure protection of our crops, our animals, our possessions of all kinds and our persons through the development of practical methods of controlling the insect pests, and, conversely, to utilize those forms of insect life that may serve a valuable purpose as destroyers of harmful kinds, that may aid in flower pollination, produce valuable products, be useful in medicine, or that may in other ways aid humanity. This goal, therefore, is the conservation of essential resources by protecting them from destruction by insects and utilizing those insects which are beneficial in one way or another.

This service which we owe to the world cannot be accomplished alone. We must recognize the services of the plant breeders, botanists, pathologists, agronomists, horticulturists, agricultural engineers, conservationists, chemists, physicists and others. We must cooperate with them in every possible way. By sincere service and cooperation with our colleagues in other sciences, we should reach that eventual goal providing better living for all through better returns for their work and through more enjoyment because of the additional leisure hours provided by the control of obnoxious insect forms.—3-15-38.

J. J. DAVIS.

REVIEW

Kranke Luzerne, by Dr. Max Klinkowski and Dr. Hans Lehmann. 132 pp., 16 figs. J. Neumann, Neudamm. 4.50 R. M.

Alfalfa is an important crop in Germany, and this publication is an excellent handbook of the afflictions to which it is subject. The sections on non-parasitic and virus diseases and on fungous diseases are by Klinkowski, that on animal pests by Lehmann. The book has been prepared particularly for practical use and treats of a range of ills from those caused by cold and hail through virus diseases, fungi, nematodes, molluscs, myriapods, mites, insects, mice and rabbits.

Both the key to injuries and the text are written in non-technical style. The affected plants and fields are well described, and the biology of the pests is treated in a brief but precise manner. The authors have discussed not only those enemies of alfalfa which frequently cause severe economic loss, but also those which are not so likely to be serious, thus enabling the grower to determine the significance of abnormal conditions. The non-biological factors which are closely related to the severity of the infection or infestation are emphasized, and cultural methods of control are frequently recommended.

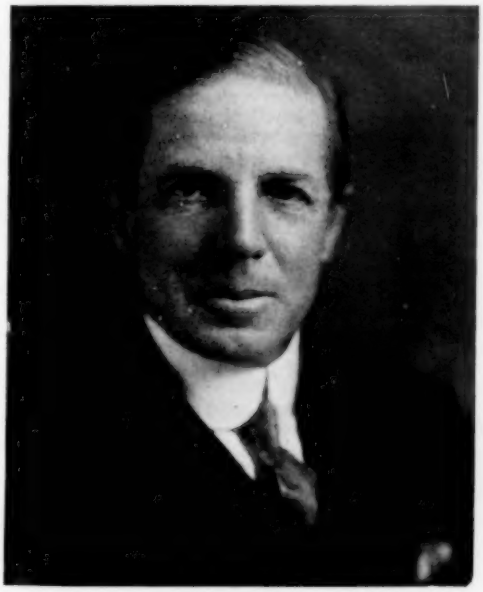
This work should appeal to any person interested in alfalfa pests, particularly in view of the possibility of such pests becoming widely distributed throughout the alfalfa growing regions of the world. The alfalfa weevil and the alfalfa snout beetle, introduced into the United States from Europe, are two outstanding cases.—1-15-38.

—R. B. Friend

OBITUARIES

Vernon Lyman Kellogg 1867–1937

With the death of Vernon Lyman Kellogg there passed one of the notable entomological workers of recent years. Always a forceful character, in whatever he was engaged upon, he added much to entomological science in his earlier years as just as in his later years he served important activities as humanitarian and as organizer of science in its broader aspects.



Harris & Ewing

Vernon Lyman Kellogg

Of his entomological service, the phase of his lifework in which this society is more directly interested, we can refer with a sense of pride in his achievement during the years in which this was his major interest.

Born at Emporia, Kansas, December 1, 1867, he was the son of Judge Kellogg, President of First Kansas Normal. He doubtless had the stimulus of scholarly associations and upon his graduation from the University of Kansas in 1889 he began his entomological career with the inspiring association of Professor F. H. Snow, then a leading naturalist of the pioneer phase of scientific study and exploration in the West. He served with Professor Snow as assistant in the teaching of entomology in official state work. In some of his most productive years he made entomological explorations of the southwest and made extended experiments with the chinch bug fungus.

His economic work included, aside from official duties, publication of papers on "Grain Insects" and "Drug Insects." In his teaching he developed useful demonstration collections for the illustration of the important insect pests of his state. His early taxonomic work on the Mallophaga added much to our knowledge of this group and he carried this study as a specialty for a number of years. His early collections in this field are carefully preserved in the entomological museum of the University of Kansas, where the development of an outstanding department of entomology and entomological museum testify to the farsighted vision of the men who laid its foundations.

After graduate training at his *Alma Mater* and at Cornell, Leipzig and Paris he was chosen to fill the chair of entomology at Stanford University where the growth of a strong department of entomology testified to his organizing ability.

In addition to his taxonomic studies on Mallophaga, he published results of studies on Mycetophilidae, on silkworm biology, insect morphology and insect behavior, which established for him a reputation as an original investigator. His valuable books, *American Insects* (1904) and *Insect Stories* (1908) showed his literary skill. His joint work with Jordan and Heath on *Animal Studies* with Jordan on *Evolution and Animal Life* and his *Darwinism Today* gave proof of his talent for analysis and clear statement of biological principles and theory.

The great service he rendered to humanity in connection with relief work in Belgium, Poland and Russia and his service to science as Secretary of the National Research Council we can only mention in passing. The former are recognized in the award of the French Legion of Honor, the Commander Order of the Crown and Order of Leopold, Belgium and Polonia Restituto, Poland. At home honorary degrees from the University of California, Brown University and Oberlin College show the esteem in which he was held by his countrymen.

With our tribute to him as a productive worker in entomology, we can add our appreciation for his example of devotion to high ideals, his sterling character and his unfailing friendship through the years.

—1-15-38.—HERBERT OSBORN

Frederick William Urich 1870–1937

So few entomologists remain long enough in any tropical country to become thoroughly familiar with and an unquestioned authority on all its problems that the career of Professor Frederick William Urich, who died at his home in Port-of-Spain, Trinidad, on July 22, 1937, is an inspiring exception. Born in Trinidad, even as a boy he was forever collecting all sorts of specimens of the luxuriant fauna and flora of this West Indian island so close to South America that they are largely continental, and his formal education in Germany and Switzerland furnished a more scientific basis for his later work.

For many years after his return to the Colony, his interest in natural history was only an avocation, but during this period he was in communication with biologists in all parts of the world, and he already had an established reputation elsewhere long before his distinctive abilities were recognized in Trinidad. A baffling malady attacking sugarcane, called by the planters "blight," which resulted in gradually decreasing yields over a period of years until the fields finally had to be abandoned, finally furnished the opportunity, and in 1909 he was appointed Entomologist for the local Board of Agriculture.

First to emphasize the possible importance of the froghopper, an insect insignificant in size and largely subterranean in habit, he made observations on all phases of its activities that were so acute that surprisingly little remained to be discovered in the more intensive studies which were later conducted on this problem. Largely as a result of this work Professor Urich was requested to conduct a similar survey at San Thomé by the Portuguese Government, and also advise at one of the large sugar Centrals near Vera Cruz, Mexico. It was while returning from Mexico that Urich first met in person the many economic and systematic entomologists in the United States with whom he had long been in correspondence, and for whom he had collected so extensively in Trinidad. At about this time also, he was working on the cacao thrips, and on the insect pests of coconuts, and in 1920 his work finally received full local recognition by appointment as Entomologist for the Department of Agriculture of Trinidad and Tobago.

In 1926 he was made Assistant Professor of Zoology at the Imperial College of Tropical Agriculture at St. Augustine, which post he held until 1935. Subsequently he took up the study of bats for the Government of Trinidad in connection with a campaign against paralytic rabies of domestic animals and man. His notable discoveries on the feeding habits of vampire bats show why cattle raising and dairying could not heretofore have become successfully established in Trinidad, and indicate in a most practical way how attacks may be prevented.

In this connection, the writer acknowledges with gratitude his solicitous advice on how to avoid personal danger on overnight field trips, as many years previously Mr. Urich had demonstrated how generally more satisfactory a small collecting net could be than the complicated large folding net with which the writer in his youthful enthusiasm had been struggling. Indeed, to one who knew him only for short periods separated by long intervals, this intimate and unselfish consideration by Professor Urich for the needs and personal idiosyncracies of the visiting scientist, coupled with a truly encyclopaedic knowledge of the local aspects of whatever problem or biologic group one might find interesting, remains for the writer as the outstanding characteristic of Professor Urich's personality.—1-11-38.

—GEORGE N. WOLCOTT

CURRRENT NOTES

SEARCH FOR PARASITES OF THE PUERTO RICAN CHANGA

George N. Wolcott, Entomologist, Agricultural Experiment Station, Rio Piedras, Puerto Rico, was in Haiti the first two weeks in December searching for parasites of the Puerto Rican changa.

PROCEEDINGS OF THE INTERNATIONAL COUNCIL OF ENTOMOLOGY

O. A. Johannsen of the New York State College of Agriculture at Cornell University makes the following suggestion: "I wish to call attention of the members of the society to the fact that, if they will register as members of the International Congress of Entomology, it will be possible for them to obtain the 'Proceedings' and 'Transactions' for the registration fee should they desire these publications. After the Congress, it is likely to cost them considerably more. Entomologists in charge of the purchase of books for the entomological libraries of the institutions find it to their advantage either to register personally or in the name of their institution."

AUSTRALIAN ENTOMOLOGIST IN THE UNITED STATES

Dr. A. J. Nicholson, Chief of the Division of Entomology of the Australian Council for Scientific and

Industrial Research, Camberra, has arrived in the United States and is working in the laboratory of Professor Harry S. Smith at the University of California Citrus Experiment Station at Riverside. Dr. Nicholson is well known for his outstanding contributions to knowledge of the principle of growth and balance in animal populations. In some of this work he has had the collaboration of Dr. V. A. Bailey, Professor of Experimental Physics of the University of Sydney. Dr. and Mrs. Nicholson expect to spend five weeks at Riverside, after which they plan to visit the Eastern United States, Canada, England, Germany and various other European countries, returning to Australia via the east coast of Africa.

BISHOPP ELECTED TO NEW POST

F. C. Bishopp, President of the American Association of Economic Entomologists during 1937, was elected President of the American Society of Parasitologists for 1938 at the recent annual business meeting of that society.

OFFICERS OF ENTOMOLOGICAL SOCIETY

Officers elected for 1938 by the Entomological Society of America at the Annual Meeting at Indianapolis, Indiana, were: A. L. Melander, *President*, William D. Funkhouser, *First Vice-President*, C. F. W. Muesebeck, *Second Vice-President*, and Clarence E. Mickel, *Secretary-Treasurer*.

SYMPOSIUM

A symposium sponsored by the Ecological Society of America, the American Association of Economic Entomologists, and the Entomological Society of America is now being arranged for the next annual meeting.

MOULTON'S REPORT

The introductory paragraph of Dr. F. R. Moulton's report of the Indianapolis meeting of the American Association for the Advancement of Science, as printed in *Science* for February 4, 1938, states, "As large as was this meeting and as fine as were its programs, its most notable characteristics were the fine spirit of cooperation among scientists in different fields and the increasing sense of responsibility of scientists to society. As an editorial in the *Washington Post* expressed it, 'the current movement might be described as an effort to shift from science for science's sake to science for the sake of humanity'."

MEETING OF NORTH CENTRAL STATES ENTOMOLOGISTS

The seventeenth annual meeting of the North Central States Entomologists was held at the Deshler-Wallick Hotel, Columbus, Ohio, March 3 to 4, 1938. The meeting opened with a general program on March 3 followed by special section meetings involving discussions of fruit insects, plant resistance, vegetable and greenhouse insects, biological control, and insects affecting man and domestic animals. Several other special conferences were held.

The meetings were attended by about 175 entomologists, mostly from the North Central States. On Wednesday evening, preceding the general program, an open house was held at the Department of Entomology, Botany and Zoology Building, Ohio State University, and at the Bureau of Entomology and Plant Quarantine Truck Crop Insect Laboratory on the south edge of the campus. The Entomologists' Dinner on Thursday night was a delightful affair enlivened by a splendid program of entertainment staged by Ohio entomologists. Professor R. C. Osburn, Head of the Department of Zoology and Entomology, Ohio State University, acted as toastmaster.

REGIONAL GRASSHOPPER COMMITTEE AT INDIANAPOLIS

The meeting of the Regional Grasshopper Committee at Indianapolis, Ind., Dec. 30, 1937, was called to order by O. S. Bare, Extension Entomologist of Nebraska, who had been asked to act as temporary chairman by Extension Director Eberle, of South Dakota. At the Sioux Falls, South Dakota, grasshopper conference in August, Director Eberle was instructed by the conference to name a regional grasshopper committee.

The first order of business was to name officers of the group—a permanent chairman and a permanent secretary. Motion was made, seconded and passed that Mr. Bare serve as chairman and Mr. Jones, of Missouri, as secretary.

Each state represented was called upon to give a report of the grasshopper control work done in 1937. The following states were represented: Colorado, California, Illinois, Iowa, Kansas, Michigan, Minnesota, Montana, Missouri, Nebraska, North Dakota, Oklahoma, South Dakota, Texas, Utah, and Wisconsin.

Dr. J. R. Parker, in charge of the Federal laboratory, Bozeman, Mont., who directed the handling of the Federal materials and summarizing of survey records in the infested areas, was called upon to give a report of the control work for 1937. Mimeograph sheets showing the estimates of bait requirement for 1938 and the use of the materials in 1937 were distributed. There was considerable discussion regarding these figures. There was general agreement among all state workers that Dr. Parker and his staff had worked hard and had handled the directing of the campaign control work in a fine manner. Dr. Rohwer, of the Bureau of Entomology and Plant Quarantine, Washington, D. C., spoke briefly regarding the change in the organization of the grasshopper control work in the Bureau for 1938. Mr. Gaddis, of the Bureau, will assume the responsibility of the work in Dr. Parker's place. Dr. Parker and his staff will continue to assist in making surveys and in carrying out the research work. Mr. Gaddis was unable to attend the conference because of poor travel connections. He hoped to reach Indianapolis on Friday in order to be present for the discussions.

Considerable discussion followed Dr. Rohwer's statements and several states reported on conditions encountered in carrying on control work in 1937.

A motion was made, seconded and passed that the chairman appoint a resolutions committee. Mr. Gilbertson, Mr. Aamodt and Mr. Dibble were named on the committee and asked to be ready for a report at the end of the meeting.

Dr. Drake, of Iowa, was asked to discuss Federal appropriation since he went to Washington last year in the interest of the various states. Several

people took part in the discussion which followed Dr. Drake's remarks. A few states reported on the conditions and the outlook for 1938 and the interest that farmers had in the work. They expressed a need for continued Federal assistance in 1938.

The Resolution Committee was called upon for its report. Mr. Gilbertson moved that we, as a group, accept the report of the legislative committee as given at the Sioux Falls conference in August, 1937 (recorded in the October number of the JOURNAL OF ECONOMIC ENTOMOLOGY), with two additional resolutions. The motion was seconded and approved. The two additional resolutions were as follows:

We further recommend that an entomologist be selected to represent the grasshopper infested states in an advisory capacity, acting with whatever agricultural agencies or other public agencies encouraging grasshopper control support.

We further recommend that the regional control committee shall call a general meeting, inviting all interested representatives when and if appropriations are forthcoming, in cooperation with Federal entomologists administering same.

The question of Federal appropriation for 1938 was discussed and a motion was made by Mr Aamodt, which was seconded and passed, that this group go on record expressing their deep appreciation of the effective work Dr. Drake, of Iowa, and others have done in securing Federal funds in the past, and that we request him to again take the responsibility of going to Washington in the interest of an appropriation. It was further moved, seconded and passed that Dr. Corkins, of Wyoming, be named as alternate to assist Dr. Drake with appropriations at Washington. In the discussion that followed, it was suggested that each state chairman of the grasshopper control work in infested areas should write a personal letter to Dr. Drake and thank him in behalf of the farmers in his state for the work done by him in making the appropriation possible.

Further discussion was had on how each state could better organize the control work during 1938.

HORTICULTURAL INSPECTION NOTES

THE TOMATO PINWORM quarantine of Colorado was revised, effective January 20, to include areas in the states designated as infested and to make certain modifications as to fumigation requirements.

A REVISION on February 8 of the Kansas quarantine relating to alfalfa weevil adds to the area designated as infested Modoc County, California, the South Dakota counties of Custer and Fall River and the Wyoming counties of Campbell, Johnson, Sheridan and Weston. The Colorado quarantine was similarly revised on January 20, not including, however, the addition of Modoc County, California, and nursery stock was again brought under the fumigation requirements in shipments to the non-infested area in Colorado.

ADDITIONAL HORTICULTURAL INSPECTION notes may be found on pages 195, 207, 275 and 277 of this issue.

NOTICE TO ASSOCIATION MEMBERS

Members of the American Association of Economic Entomologists benefit mutually by an exchange of news relating to their profession. Notices of meetings, items about change of position and news of current research activities appearing in the JOURNAL are read with interest by Association members. Current notes of this character should be sent to the Associate Editor, Dr. H. B. Weiss, 616 First Mechanics National Bank, Trenton, N. J.

PROCEEDINGS OF THE NINTH ANNUAL MEETING

EASTERN BRANCH, AMERICAN ASSOCIATION OF ECONOMIC ENTOMOLOGISTS

The Walton Hotel, Philadelphia, Pa., November 18 and 19, 1937

The meeting was called to order by Chairman Harlan N. Worthley. Mr. Lee A. Strong, Chief of the Bureau of Entomology and Plant Quarantine, spoke of the various research projects in his Bureau which had received increased appropriations, in some cases substantial ones. Mr. Strong also mentioned the creation of a new position, that of Assistant in Research to the Chief of the Bureau.

The Chairman appointed the following committees:

Committee on Nominations: W. J. Schoene, William Moore.

Auditing Committee: L. A. Stearns, H. F. Dietz.

Committee on Resolutions, T. J. Headlee, J. L. Horsfall, T. L. Guyton.

The report of the Secretary-Treasurer was read and referred to the Auditing Committee.

REPORT OF THE SECRETARY-TREASURER

A record of dues received from Eastern Branch members in 1936, together with similar information for previous years, is shown in the following table:

STATE	1929	1930	1931	1932	1933	1934	1935	1936
West Virginia	1	1	1	2	2	2	3	0
Virginia	5	4	8	5	4	5	9	3
District of Columbia	6	3	0	2	5	6	14	7
Maryland	5	6	9	3	4	5	9	6
Delaware	2	2	3	1	2	5	5	7
Pennsylvania	9	3	11	5	15	13	12	7
New Jersey	26	21	19	11	23	20	23	19
New York	27	28	39	25	23	25	26	33
Connecticut	10	9	15	5	6	7	7	10
Rhode Island	2	0	1	0	0	0	1	1
Massachusetts	6	5	14	8	4	3	4	3
Vermont	1	1	0	0	0	0	1	0
New Hampshire	0	0	1	1	0	0	0	0
Maine	0	1	2	1	0	1	2	1
Canadian Provinces	1	0	0	0	0	0	1	0
Outside E.B. Territory								3
TOTALS	101	84	132	69	88	92	117	100

FINANCIAL STATEMENT

Balance on hand, November 2, 1936		$1,434.04
Receipts		
Additional dues for 1936	$ 146.00	
Receipts due to sale of Directory space, listings, and Directories	2,215.04	
Dues for 1937 (to November 10, 1937).	64.00	
	$2,425.04	$3,859.08
Disbursements		
Expenses of Chairman	3.12	
Lantern Operator (2 days)	10.00	
Printings of 1935 Proceedings	456.00	
Printing in connection with Directory	61.50	
Stationery & supplies in connection with Directory	36.83	
Stationery, Eastern Branch	6.50	
Clerical Services for Directory	173.32	
Clerical Services for Eastern Branch	18.69	
Stamps for Directory	60.00	
Stamps for Eastern Branch	15.50	
Printing 1937 Directory	710.25	
Printing 1936 Proceedings	260.00	
Total Disbursements		1,811.71
Balance on hand November 10, 1937 (Deposited in Trenton Trust Co.)		$2,047.37
Bills collectible	$71.00	

HARRY B. WEISS

The following report of the Finance Committee was read and adopted:

REPORT OF THE FINANCE COMMITTEE

Since the last meeting of the Eastern Branch of the American Association of Economic Entomologists the Finance Committee has had several meetings. As a result of these meetings a second edition of Entoma was prepared and published about the middle of July.

This second edition was entirely revised and considerably enlarged. The general information on insecticides and fungicides was placed in the front of the book and followed by the listings of insecticides, fungicides, materials used in insecticides and fungicides, entomological supplies, etc., etc., and lastly by the advertisements. The portion giving information on insecticides was completely revised and information on fungicides was added. We are indebted to Dr. R. P. White, Associate Plant Pathologist of the New Jersey Agricultural Experiment Station for this information.

The listings on insecticides and materials used in insecticides were also revised by the addition of fungicides and materials used in their manufacture. Further radical changes consisted in listing under the heading "Insect Pest Exterminating and Fumigating Companies," the complete membership of the National Association of Exterminators and Fumigators. The entire membership of the National Shade Tree Conference was also included under the heading "Commercial Companies Caring for Trees." Other portions of the listings were revised and added to.

The pages of advertising were increased from 34 in the first issue to 42 in the second. Considerable interest has been shown by the advertisers in Entoma and it is possible that, if additional time and effort were given to the next edition, the number of advertisers could be considerably increased.

Members of the National Association of Exterminators and Fumigators have purchased a number of copies of Entoma; 100 copies were sent to their annual meeting, October 27 and 28, at Memphis,

Tenn. A report on the number of copies sold has not been received.

The membership of the Phytopathological Society of America should be solicited. This has not yet been done.

The response from the advertisers in Entoma and those who have received it through membership in the American Association of Economic Entomologists as well as those purchasing it has been very encouraging and should warrant a third edition in another two years.

Attached hereto is a financial statement of receipts and expenses incurred in the office of the editor of Entoma.

FINANCIAL STATEMENT FOR PERIOD FROM NOVEMBER 9, 1936, TO NOVEMBER 1, 1937

This report is independent of the copies of the Second Edition of Entoma sent out to members of the American Association of Economic Entomologists or members of the Eastern Branch of the American Association of Economic Entomologists.

FINANCIAL STATEMENT, NOVEMBER 9, 1936, NOVEMBER 1, 1937

Copies of 1935 Edition Entoma sent out gratis	7			
Copies of 1937 Edition Entoma sent out gratis	7			
Cash Receipts				
Copies of 1st Edition of Entoma sold for 25 cents each	43	$ 10.75		
Copies of 1st Edition of Entoma sold for 50 cents each	6	3.00		
Copies of 1st Edition of Entoma sold 3 for $1.00	3	1.00		
Copies of 2nd Edition of Entoma sold for 75 cents each	29	21.75		
Postage received in cash		1.32		
Total cash receipts for Entoma			$ 37.82	
Receipts in Stamps				
Copies of 1st Edition of Entoma sold for 25 cents each	19	$ 4.75		
Copies of 1st Edition of Entoma sold for 50 cents each	23	11.50		
Copies of 2nd Edition of Entoma sold for 75 cents each	12	9.00		
Miscellaneous stamps		1.38		
Total stamp receipts for Entoma			26.63	
Cash Due				
Copies of 1st Edition of Entoma sold for 25 cents each	63	$ 15.75		
Copies of 1st Edition of Entoma sold for 50 cents each	7	3.50		
Copies of 2nd Edition of Entoma sold for 75 cents each	25	18.75		
Copies of 2nd Edition of Entoma sold for $1.00 each	1	1.00		
Total cash due			39.00	
			$103.45	
Cash Statement				
Balance from 11/27/36		$ 20.07		
Received from paid listings		26.00		
Received from Mr. Weiss for stamps		60.00		
			106.07	
Grand Total				$209.52
Disbursements				
Cash sent to Mr. Weiss		$ 15.50		
Cash used for stamps	$117.00			
Supplies, etc.	6.39	123.39		
Cash on hand		5.00		
Stamps used which were received in payment for Entoma		26.63		
Total Disbursements			$170.52	
Cash Due			39.00	
Grand Total				$209.52

October 31, 1937

CLYDE C. HAMILTON, *Chairman*
J. L. KING
A. E. BADERTSCHER
J. L. HORSFALL
A. WEED
H. B. WEISS

Mr. V. I. Safro made the following motion which was adopted during the final business session on November 19:

"That an annual medal be awarded to the member of the Eastern Branch for that paper presented at the Annual Meeting of the Branch, that shall represent, in the opinion of the judges, to be appointed each year by the Chairman of the Branch, the best contribution to the Science of Economic Entomology.

"For this purpose the Chairman of the Eastern Branch shall appoint a Committee of three members to establish the conditions under which the award shall be made, the rules of eligibility of papers, details as to manuscripts and their publication, the value, nature and purchase of the medal and such other matters in connection herewith as will permit the granting of the annual award to begin with the Annual Meeting in 1938

"The conditions as established by the Committee shall be transmitted to the Secretary of the Branch who will announce them to the Membership as soon as practicable."

Chairman Worthley called for the reports of the following committees.

REPORT OF AUDITING COMMITTEE

We have audited the accounts of the Secretary-Treasurer and find them to be correct.

L. A. STEARNS
H. F. DIETZ

Following the adoption of the above report, the report of the Secretary-Treasurer was adopted by the Branch.

REPORT OF COMMITTEE ON RESOLUTIONS

WHEREAS Peter Walter Claassen, one of our distinguished members, has been removed by death, and

WHEREAS, by Dr. Claassen's passing, we have lost an outstanding scholar and an inspiring teacher, and

WHEREAS, our deep sense of loss is beyond adequate expression, now

Be it Resolved, that we hereby indicate our recognition of this great loss and our sympathies for Mrs. Claassen, and

Be it Further Resolved, that a copy of this resolution be sent by our Secretary to Mrs. Claassen, that she may know of our high esteem of the deceased and of our sympathy with her in her great loss.

WHEREAS, Leon Howard Worthley, one of our most distinguished members has been removed by death, and

WHEREAS, in Mr. Worthley's passing, we have lost a most outstanding leader engaged in practical insect control, and

WHEREAS, our deep sense of loss is quite beyond adequate expression, now

Be it Resolved, that we hereby indicate our recognition of this great loss and our sympathy for Mrs. Worthley, and

Be it Further Resolved, that a copy of this resolution be sent by our Secretary to Mrs. Worthley, that she may know of our appreciation of the deceased and of our sympathy with her in her bereavement.

WHEREAS, the Eastern Branch of the American Association of Economic Entomologists has always desired to have the papers read at its meetings published as a group as proceedings; and

WHEREAS, it has until within the last two years been able to secure this consideration; and

WHEREAS, for the last two years its papers have appeared in scattered numbers, leading to much objection and criticism from its members; and

WHEREAS, this condition appears to have been due to the operation of the Priority Rule and exceptions made thereto, and to the failure on the part of members of the Eastern Branch to file papers promptly; now

Be it Resolved, by the Eastern Branch of the American Association of Economic Entomologists, in meeting assembled in Philadelphia, Pennsylvania, this 19th day of November, 1937, that the Executive Committee of the American Association of Economic Entomologists, be, and they hereby are, requested to make such changes and arrangements as are necessary to afford the Eastern Branch publication of its papers as a group or proceedings; and

Be it Further Resolved, by the Eastern Branch, that in order to promote this objective, the following plan of procedure be, and is hereby presented to the Executive Committee for its consideration:

(1) All papers read before the Eastern Branch shall be filed with the Editor of the JOURNAL OF ECONOMIC ENTOMOLOGY on or before January 1st of the year following each meeting of the Eastern Branch. All such papers not presented by this date shall be considered as individual papers and will not be printed as part of the Eastern Branch proceedings.

(2) That these papers shall be published as a group in the April issue of the JOURNAL.

(3) That the Executive Committee recommend to the American Association of Economic Entomologists for action at its Indianapolis meeting such changes in the Priority Rule, with the exceptions thereto, as may be necessary to secure this desired objective.

WHEREAS, the results of the labors of the Finance Committee of the Eastern Branch are obvious to all and have placed our Branch in excellent financial condition, now

Be it Resolved, that the sincere thanks and appreciation of the Eastern Branch be, and is hereby, tendered to this Committee, and especially to its able Chairman, Dr. Clyde C. Hamilton.

T. J. HEADLEE
J. L. HORSFALL
T. L. GUYTON

REPORT OF COMMITTEE ON NOMINATIONS

For Chairman, V. I. Safro
For Vice-Chairman, C. C. Hamilton
Secretary-Treasurer (for 3 years) H. B. Weiss

W. J. SCHOENE
WM. MOORE

These reports were adopted by the Branch, and the various officers were elected.

Following his election, Mr. Safro took the chair and conducted the last afternoon session. At this time Mr. F. C. Bishopp, President of the American Association of Economic Entomologists, told of plans for the Indianapolis meeting and extended an invitation for everyone to attend.

The interest at all sessions was good, and the attendance totaled 150. The following members and guests registered during the meetings:

Amos, J. M.
Annand, P. N.
Arnold, R. B.
Badertscher, A. Edison
Bailey, Harold L.
Baker, R. M.
Baker, Walter C.
Beckwith, C. S.
Birdsall, R. W.
Bishopp, F. C.
Buchanan, W. Dwight
Buchholz, A. B.
Buettner, W. O.
Burgess, Emory D.
Britton, W. E.
Campbell, F. L.
Carman, Glenn E.
Chisholm, Robert D.
Clark, Charles A.
Collins, C. W.
Collins, Donald L.
Cory, Ernest N.
Costigan, Stella M.
Craig, F. Waldo
Darley, Merrill M.
Dean, R. W.
Dickison, William
Dietz, Harry F.
Dills, L. E.
Ditman, L. P.
Dorman, Russell
Driggers, B. F.
Dyc, H. W.
Eastman, Perley M.
Ewart, W. H.
Felt, E. P.
Fenton, Alfred
French, G. T.
Friend, R. B.
Gambrell, F. L.
Gardner, T. R.
Garman, Philip
Gemmell, Louis G.
Ginsburg, J. M.
Goddin, A. H.
Goodhue, Lyle D.
Granett, Philip
Guy, H. G.
Guyton, Thomas L.
Hadley, C. H.
Haeussler, G. J.
Hamilton, Clyde C.
Hammer, O. H.
Hatcher, R. F.
Heal, Ralph E.
Hough, W. S.
Jaynes, H. A.
Jefferson, R. N.
Johnson, J. Peter
Jones, M. P.
Jones, T. H.
King, J. L.
Lathrop, F. H.
Leiby, R. W.
Leonard, M. D.
Lincoln, Charles
MacCreary, Donald
MacLeod, G. F.
Mande, William J.
Martin, Charles H.
McGovran, E. R.
McConnell, H. S.
Menusan, H., Jr.
Moore, Joseph B.
Moore, William
Nelson, R. H.
Nelson, Franklin C.
Nottingham, J. O.
Orr, Leslie W
Osborn, H. T.
Pepper, B. B.
Pepper, J. O.
Peterson, P. D.
Pierpont, Roger L.
Poos, F. W.
Porter, B. A.
Pyenson, Louis
Rawlins, W. A.
Readio, P. A.
Rex, E. G.
Richmond, E. A.
Roark, R. C.
Safro, V. I.
Sanders, J. G.
Schmitt, John B.
Sherman, R. W.
Soraci, F. A.
Steiner, Harold M.
Stene, A. E.
Stockwell, C. W.
Stoke, Henry W.
Tischler, Nathaniel
Thomas, C. A.
Townsend, James F.
Turner, Neely
Van Horn, M. C.
Vreeland, Cornelius D.
Wade, J. S.
Wadley, F. M.
Walker, G. L.
Watkins, T. C.
Weigel, C. A.
Weigel, E. W.
Weiss, H. B
Whall, Harry H.
White, Richard P.
Worthley, H. N.
Yetter, W. P., Jr.
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